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The Volatility of Unlisted Infrastructure Investments

Valuation drivers and trends, 2000-2021

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EDHECinfra
building benchmarks
for infrastructure investors

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Foreword

Since its inception, LTIIA has supported research by academic centres such as EDHECinfra aiming to promote useful and robust research findings about unlisted infrastructure as an asset class.

This paper on the drivers of unlisted infrastructure volatility contributes to supporting better data and the development of analytical tools and performance benchmarks for the investment community, which we see as one of our main responsibilities.

Why have we chosen such a theme?

Investing, as we all know, is the art of balancing risk and return, and volatility is a proxy for risk. A commonly accepted driver for investing in Infrastructure is the lower level of risk that it is supposed to offer, due to the essential nature of the services provided which should not vary too much in relation to the ups and down of the economy.

Understanding and managing the volatility of unlisted infrastructure returns should be an essential part of an infrastructure fund manager's job. But this is where the challenge begins: Unlisted infrastructure risk and performance does not lend itself easily to be measured, due to the lack frequent transactions and their private nature. It can be difficult to manage what you cannot measure.

This is a key concern for Long term investors like LTIIA members, often focused on buy-and-hold strategies, and who need to get a better understanding of the drivers of risk and the benchmarks of performance over a long horizon to inform their strategic asset selection and portfolio allocation. Robust risk measurement is also a key component of prudential reporting requirements.

This is a where the work performed by EDHECinfra is essential: the analysis presented here uses a unique database of unlisted infrastructure equity investments coupled to a new approach to measure their fair market value over time: thanks to this methodology which predicts actual market prices accurately, it is possible to measure the variability of unlisted infrastructure equity prices and describe the factors that explain it. the paper finds a higher return volatility than is often perceived: while cash flows are rather stable over time, the long life of infrastructure investments make them sensitive to changes in discount rates, themselves driven by interest rates and risk premia.

There are many more interesting findings on how systemic risk factors drive expected returns, also extending to corporate infrastructure in this paper.

I hope you will find this report useful and wish you an instructive read.

Thierry Déau

President, LTIIA

CEO & Founder, Meridiam

About the Authors

Frédéric Blanc-Brude is the Director of EDHEC Infrastructure Institute, a dedicated research unit developing a unique body of applied research on infrastructure investment from the perspective of large asset owners. He is also the CEO of Scientific Infra, a provider of unlisted infrastructure equity and debt index data and analytics. He founded EDHEC*infra* in 2016.

Abhishek Gupta is Head of Product Development, leading applied research and client solutions. He previously worked in the asset management industry with a ofcus on real assets. He holds a Masters of Science in Financial Engineering from Nanyang Business School and a Bachelor of Technology from the Indian Institute of Technology.

Luna Lu is an analyst in the EDHECinfra data team. She previously worked as an external auditor in one of The Big Four accounting firms in Singapore with diverse experience in various industries. Luna is an Associate Member of CPA Australia and holds a Bachelor of Commerce in Accounting and Finance.

Amanda Wee is an analyst in the EDHECinfra data team. Prior to joining EDHECinfra, she worked at one of the Big 4 Accounting Firms in Singapore specialising in external audit. She holds a Bachelor of Science (Honours) in Accounting and Finance from the University of London and is a member of CPA Australia.

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In this paper, we examine the drivers of the volatility of unlisted infrastructure equity investments, that is, the reasons why the market prices of such investment can and do vary over time.

The volatility of infrastructure equity investments is the risk which investors take to receive a reward for holding such assets. A robust measure of this risk and its drivers is an essential part of the inclusion of infrastructure investments in the portfolio, from strategic asset allocation to risk management and reporting, to manager compensation.

However, measuring this risk is difficult because the only available data is often limited to quarterly appraisals that do not reflect the current state of market prices but are instead 'stale' i.e. backward-looking and lead to very 'smooth' returns, exhibiting highly unrealistic (low) levels of risk per unit of return. Appraisal-based indices typically report unrealistic total return volatility in the 2-3% range, leading to very high and unrealistic risk-adjusted returns (Sharpe ratio above 3).

Our analysis uses the EDHECinfra database of unlisted infrastructure equity investment data, which covers hundreds of firms over 20 years and a new approach to measure the market value of these investments over time. Thanks to this technology, which predicts actual market prices very precisely, it is possible to measure the variability of unlisted infrastructure equity prices and to describe its fundamental components.

The market value of these investments is determined by the combination of expected cash flows (dividends), and a discount rate that combines a term structure of interest rates (the value of time) and a risk premia to compensate investors for the uncertainty of the future payouts. On average, the applicable market discount rate is also a reflection of investors' expected return.

Using our approach to mark unlisted infrastructure to market, we find that the combination of changes in expected dividends (e.g. following a change in demand for transport services or energy) and of changes in expected returns lead to a level of total return volatility in the 7-12% range. The resulting risk-adjusted returns are realistic while still attractive.

Looking at the components of the change in market value of unlisted infrastructure, we find that infrastructure equity risk can be driven at least as much by changes in expected cash flows than by changes in expected returns. This is an important and sometimes neglected aspect of the risk of investing in infrastructure: while cash flows are typically understood to be quite stable, the long-life of infrastructure investments makes their value sensitive to changes in discount rates. Therefore, assessing the evolution of investors' expected returns in unlisted infrastructure equity is essential to arrive at robust measure of risk at any point in time.

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Key Findings

We report the following stylised facts on the causes and trends of the volatility and market prices of unlisted infrastructure equity:

- **A shift in valuations after 2008**: Our results confirm the oft-mentioned anecdotal evidence that unlisted infrastructure valuations have increased a lot since 2008-09. In fact, the realised volatility of unlisted infrastructure investments is in part the result of the development of the asset class and an increase in valuations which reflects a systemic increase in the level of demand for these assets and therefore a significant one-off shift in the price of unlisted infrastructure equity risk between 2009 and 2016. Before 2008, the average market expected returns for unlisted infrastructure equity was in the low double-digits but decreased steadily after that to reach a trough of 6% towards the end of 2016.

- **'Peak infra' was in 2017**: We also find that after 2017, average expected returns reach a new 'steady state' between 7 and 8%. Thus, despite frequent claims that infrastructure assets are continuously getting more expensive, we confirm the previous empirical findings of Blanc-Brude and Tran (2019) that 'peak infra' (the highest average level of valuations) was reached in the 2016-17 period and that unlisted infrastructure valuations have been following a different path since then.

- **Expected returns spike during crises**: Since 2020, the average level of expected returns has breached 8% for the first time since 2015. We note similar spikes during the 2008 financial crisis, 2012, Eurozone debt crisis, Brexit, etc.

- **Duration is a good measure of forward-looking risk**: A significant proportion of the realised volatility of unlisted infrastructure returns in the past 15 years is the result of this re-valuation i.e. one-way capital gains that were created by a significant increase in the demand for such assets. Still, unlisted infrastructure remains volatile and exposed to the same risks, but realised volatility over the past two decades is perhaps not the best proxy of the asset class forward-looking volatility.

  We shows that in the more recent period (past five years), the volatility of private infrastructure asset prices has been mostly driven by a combination of movements in interest rates and risk premia, the magnitude of which is much greater than changes in future dividends. It follows that the duration of unlisted infrastructure equity (its sensitivity to discount rate changes) is the most informative forward-looking measure of risk. We report significant levels of duration between 7.6% to 11.6% in Q1 2021 depending on TICCS® segments. Duration presents the advantage of combining the impact of changes in the risk premia (which is systematic but firm specific) with that of interest rates, which is country specific.

- **Systematic risk factors drive expected returns**: We show that the risk premia of

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individual private infrastructure companies is driven by a combination of micro-economic and macro-economic factors, which are consistent with academic research and financial theory. These changes in the determinants of the price of equity risk are at the heart of the volatility of private infrastructure. In particular:

1. The Leverage factor premium, which is the largest contributor to the discount rate has halved since 2010 but reversed its course in 2020. In line with financial theory, higher leverage commands a higher premia, even though this effect tails off rapidly on average for highly leveraged assets, which, by design, tends to be the safest infrastructure projects.

2. The Size factor premium exhibits more short term volatility and reached a floor in 2015. This factor can be considered a proxy of the relative liquidity of infrastructure investments: *ceteris paribus* larger assets command a higher premia. This result sometimes seems to contradict the anecdotal evidence that large 'trophy' assets command higher prices (and therefore lower premia) in the market. However, this suggestion ignores the independence of factors premia. High prices for highly-demanded large assets are the result the combined effect of all risk factors. Indeed, large sought-after infrastructure companies also tend to be highly profitable.

3. The Profit factor premium is the the only negative contributor to aggregate risk premia: higher profits lead to lower risk premia (higher valuations). This factor premium has achieved a full rotation since 2000, reaching a peach in 2012 when higher profits barely achieved a higher valuation and returning to its 2000 level by 2020. This factor can be interpreted as a sign of greater risk aversion amongst buyers of unlisted infrastructure. In this sense, it reached its lowest level in 20 years just before the Covid-19 pandemic. Negative profits (leading to a higher premium) are also a contributor to the so-called 'greenfield' premium which characterises early development projects.

4. The Investment factor premium exhibits the most stability over the past 20 decades. High investment (capex) in infrastructure companies is related to the life-cycle of the firm, including the greenfield phase during which sinking larger amounts of capex commands a higher premium. Investment also contributes to a greenfield premium.

5. Country risk (term spread): a steeper yield curve indicates greater long term uncertainty which, in the case of infrastructure can be associated with country risk and tends to increase the risk premia.

6. A range of control variables including business model and industrial activities

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according to the TICCS® taxonomy of infrastructure companies, in particular their business model and corporate structure. For instance When infrastructure companies collect risky revenues either based on demand or traffic, they command a higher risk premia than in they do not (and are either contracted or regulated).

Thus, investments in unlisted infrastructure equity can be characterised as investing in a combination of exposures to a time-varying (infrastructure) equity risk premia, as well as a significant amount of interest rate risk. It is these effects that explain the non-negligible volatility of unlisted infrastructure equity investments, which is itself the reflection of investors risk preferences and perception of the uncertainty with which expected dividends may be paid, including not at all (bankruptcy risk).

A granular range of risk profiles

Because risk factor exposures vary between different segments of the unlisted infrastructure market, a range of risk profiles exists, some of which are shown in table 1, which shows that returns can be negative and variable, more so in certain segments that are exposed to market risk (e.g. Merchant infrastructure) and less so in contracted projects which tend to have a lower duration and less risky cash flows hence a lower but also less volatile risk premia. We also see that in the cross-section of TICCS segments the range of risk and return profiles is significant.

Convergence with public market prices for comparable assets

We provide an additional robustness test of these results by way of a natural experiment: we consider 14 listed funds that only invest in unlisted infrastructure equity with negligible additional fund-level leverage and a well-defined focus on UK social and renewable energy projects which we can easily map to the TICCS® classification of infrastructure assets and create a private proxy of these funds with the EDHECinfra index data.

We use the reported appraisal NAV, appraisal discount rates and traded price of these funds to show that their market-implied expected returns (discount rate adjusted for the NAV premium) have been converging with the expected returns of the equivalent segment of unlisted infrastructure equity. This finding confirms that unlisted infrastructure used to trade at a significant (price) discount to comparable listed assets but that this gap narrowed quickly as the asset class became more in demand and even overshot public market expected returns between 2016 and 2018. Since 2018, we find that expected returns have converged for two listed and unlisted baskets of the same UK renewable energy and social infrastructure projects (see figure 1).

We conclude that a robust measure of the volatility of unlisted infrastructure equity is possible because it relies on an equally robust asset valuation technology. This highlights the importance of taking duration into account when investing in infrastructure to anticipate changes in the market values of unlisted

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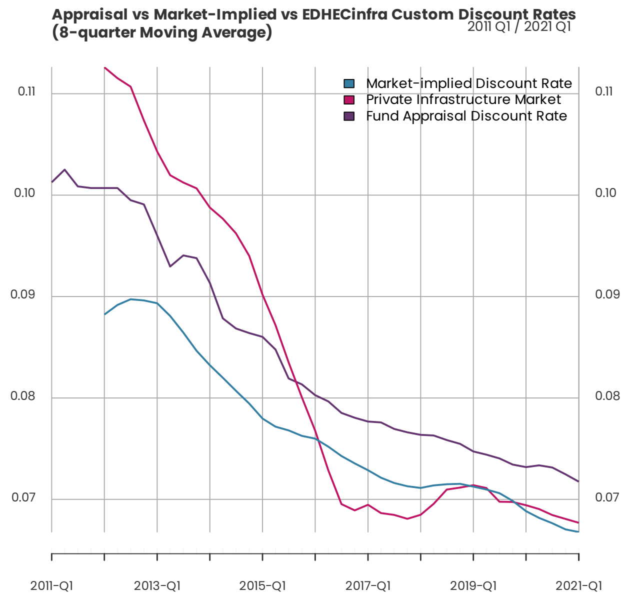
Table 1: Total Returns, Risk and Expected Returns of the Unlisted Infrastructure Asset Class and Selected TICCS® Segments, Data as of Q1 2021

Indices	1-year total return	5-year total return	5-year volatility	10-year total return	10-year volatility	99.5% 1-year VaR	Max drawdown	Duration	Expected returns
infra300®	-3.92%	4.08%	9.79%	13.46%	12.69%	21.21%	13.75%	8.69%	8.8%
Global Infrastructure	-1.15%	6.42%	9.68%	14.64%	12.35%	18.97%	13.70%	8.03%	8.6%
Contracted	2.81%	6.62%	8.13%	14.79%	11.26%	14.98%	10.35%	7.67%	7.7%
Merchant	-3.37%	5.82%	11.77%	14.38%	14.63%	27.18%	21.60%	7.70%	10.6%
Global Transport	-4.22%	6.16%	11.45%	15.17%	14.93%	26.90%	22.41%	8.56%	8.7%
Airports	-19.79%	-0.92%	16.22%	11.85%	17.78%	36.00%	34.89%	11.63%	8.9%
Global Projects	0.97%	7.88%	9.07%	15.73%	12.03%	17.02%	13.93%	7.66%	8.2%
Global Wind	-0.25%	7.86%	8.19%	15.22%	10.48%	11.37%	9.55%	7.40%	6.6%
Global Core	0.96%	9.43%	7.33%	15.04%	10.36%	12.46%	11.16%	7.73%	6.2%
Global Core+	-1.88%	10.95%	9.67%	17.94%	12.40%	14.62%	11.86%	9.19%	9.1%
Mid-Market	-0.11%	11.13%	9.40%	16.88%	10.94%	12.07%	10.88%	7.70%	8.8%
Range in bps*	2,260	1,210	890	610	740	2,460	2,530	420	440

Source: EDHECinfra. * maximum - minimum value. As of Q1 2021, local currency returns. 99.5% one-year Cornish Fisher VaR. Expected returns as of Q1 2021. TICCS® segments except for Core and Core+, represented by the first two and the third quantiles of expected returns, respectively and mid-market, which is defined as the second and third size quantiles in the universe.

Figure 1: Rolling average of Appraisal Discount Rates and Market-Implied Discount Rates for comparable baskets of UK renewable energy and social infrastructure projects



Source: Datastream, Annual and Quarterly Reports, EDHEC*infra*

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infrastructure equity. For a given stream of cash flows, a large part of this risk is driven by a country-specific (or macro) component (the yield curve) and a firm-specific (but systematic) component which is the combination of the risk factor exposures and the market price of these same risk.

Despite the *a priori* view that infrastructure is low risk, and the myopic perception of very low return volatility created by appraisals, infrastructure equity investments are risky and exhibit a non-negligible level of volatility, albeit an attractive risk-adjusted return profile.

These findings are essential for the good management and monitoring of unlisted infrastructure. With adequate and believable measures of volatility, infrastructure can be addressed from a total portfolio perspective (strategic allocation), from a prudential perspective (e.g. Solvency-II) using methods that apply across asset classes.

In fine, the understanding and documentation of the volatility of unlisted infrastructure condition its development as a fully-fledged asset class.

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1. Is infrastructure volatile?

1. Is infrastructure volatile?

In this paper, we discuss the volatility of unlisted infrastructure equity investments market prices and returns.

Risk is an important issue for long-term investors in infrastructure. Without a robust measure of risk, it is not possible to manage infrastructure as an asset class. Measures of the volatility of the returns of infrastructure investments and of their correlations with other asset classes are necessary to determine the role of infrastructure in any strategic asset allocation. Precise risk measurements are also an essential component of the prudential reporting requirements of many investors. Finally, understanding the risk drivers of these investments enables more transparent infrastructure investment strategies and products to be defined, and assists in deciding on the right allocation and performance benchmarks.

While infrastructure investments are typically understood to be low risk and characterised by a stable business model with predictable long-term revenues, they are nevertheless exposed to certain risks. These risks, some of which are common to all infrastructure companies, create the potential for financial losses, as is the case with any financial investment.

From a fair market value perspective, beyond the future cash flows themselves, a distinction can be made between the uncertainty of expected cash flows, which commands a risk premium, and interest-rate risk, which is common to all long-term financial assets.

Regarding the latter, an intuitive example is provided by an index of long-term US Treasury bonds with 30-year maturity. The cash flows of these instruments can be considered risk-free since the US government has an excellent credit rating. These instruments therefore do not command a risk premium and are used to define the risk-free rate of interest. Yet, such an index has a 10-year total return volatility of more than 18% [1]. This 'duration' or interest-rate risk of long-term investments is naturally found in infrastructure equity investments as well, with streams of expected dividends stretching several decades into the future.

Moreover, unlike US Treasury bonds, the cash flows of infrastructure equity investments are not risk free. While it is reasonable to assume a degree of independence from the business cycle for most types of infrastructure assets in good times, bad times can also impact infrastructure, as the Covid-19 lockdowns illustrate. Moreover, some types of infrastructure companies are at least partly correlated with the business cycle even in good times, such as large airports, toll roads, ports and utilities.

A review of the historical outcomes of infrastructure investments confirms that they can be impacted by the state of the economy. For instance, in the 650+ companies tracked in the EDHEC*infra* broad market universe, over the past 20 years we observe more than 150 events of default or dividend lock-up, several dozen events of bankruptcy and more than a dozen events of termination by the public sector. These defaults and bankruptcies are typically found in companies that have a 'merchant' business model (e.g. after a recession) or stem from structural shifts affecting an entire industrial sector (e.g.

1 - Source: Datastream

1. Is infrastructure volatile?

electricity market prices permanently lower than the marginal production cost of older power plants).

Not only do infrastructure equity investments command a risk premium due to the uncertainty of their future dividends, this premium is the *market price* of infrastructure equity risk and, like any market price, changes over time with the supply of and demand for unlisted infrastructure equity.

Over the past decade and a half, the demand for unlisted infrastructure investments has increased considerably as institutional investors, in search of yield and diversification, began adding this asset class to their portfolios. In effect, this increase in demand, and the corresponding decrease in the market price of unlisted infrastructure equity risk, has been a source of volatility in itself since asset prices have *changed* considerably over that period. Since return volatility is simply a reflection of the variability of market prices, large changes in the market price of infrastructure companies contribute to return volatility.

Thus, we expect the market value and returns of unlisted infrastructure investments to be volatile for three main reasons:

1. Changes in expected cash flows, which can be due to asset-specific or market-specific factors. In the second case, they are common to all assets in the relevant market segment;
2. Changes in the market price of unlisted infrastructure equity risk, as a result of the supply and demand for these assets and of the evolution of the risk itself e.g. Covid-19 made the dividends of airport companies more uncertain.
3. Changes in the term structure of interest rates since, like bonds, several decades of future cash flows should be discounted using the appropriate term structure, representing the risk-free equivalent at the same horizon.

In the rest of this paper, we first examine the volatility of unlisted infrastructure equity investments implied by the appraisals reported by investment fund managers. Until recently, the only available price information was the net asset values, or NAVs, reported in the context of quarterly appraisals. However, appraisal data is famously ill-suited to measure risk, as we confirm in the next section.

Next, we describe a new methodology to estimate the determinants of unlisted infrastructure market prices and therefore measure the associated variance of these prices i.e. the volatility of unlisted infrastructure equity. We show that this approach is robust and predicts actual transaction prices well. Hence, it provides a good approximation of the risk of these assets. Indeed, the resulting risk-adjusted returns, while attractive, are found to be realistic, unlike appraisal-based estimates of risk-adjusted returns.

We show that unlisted infrastructure market prices are driven by a combination of the three effects listed above (cash flows, interest rates and a risk premium) and that the impact of

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interest rates changes, and of the evolution of the infrastructure equity risk premium, play an important role in explaining volatility. This is the case over and above the impact of changes in expected dividends, especially in 'bad times' such as the Covid-19 lock-downs.

Finally, we present a further robustness test of these results by examining the market valuations of 14 publicly-listed infrastructure investment funds that solely invest in unlisted infrastructure equity, primarily in the social infrastructure and renewable energy sectors in the UK. These vehicles provide a useful natural experiment insofar as they can be directly compared with equivalent private market returns and risk for similar investments. Using the EDHEC*infra* database, we build a custom private market proxy of these public funds and confirms the validity of our approach for the broader unlisted infrastructure sector both in terms of estimating value and risk.

In the end, measuring the true volatility of unlisted infrastructure investments helps highlighting the qualities and opportunities created by this asset class for long-term investors. It facilitates making informed choices in terms of risk management and reporting, asset allocation, liability hedging and performance monitoring by providing a risk-adjusted view of the asset class.

The rest of this paper is structured thus: in section 2, we review detailed appraisal data for a sample of infrastructure funds and confirm that the risks of unlisted infrastructure investments are not captured but this type of data. In section 3, we propose an analysis of the drivers of fair value in unlisted infrastructure equity investments, describe how it can measured effectively and review granular risk profiles including by TICCS® segment and other styles (Core, Core+ etc.). In section 4, we conduct a further robustness check of these results by examining the returns and discount rate risks of unlisted infrastructure assets found in listed infrastructure trusts. Section 5 concludes.

2. Appraisals are stale

2. Appraisals are stale

Until recently, the only data available to assess the volatility of unlisted infrastructure investments was the reported net asset values (or NAVs) resulting from regular appraisals of individual assets.

In the case of unlisted infrastructure equity, appraisals are typically produced using the 'income' or discounted cash flow approach, by which the value of the asset is:

$$P_j = \sum_{t=1}^{T} \frac{D_{j,t}}{(1 + r_t + \gamma_j)^t}$$

where T is the investment's expected life, r_t is the risk-free rate at each point in time until date T and γ is the deal's risk premia.

In practice, r_t is typically set to be a moving average of long-term bond yields and γ is also a long-run average usually based on the capital asset pricing model or CAPM. While these estimates do vary over time (see for example KPMG, 2020), they are typically 'smooth' i.e., they do not reflect the current latest market conditions but rather tend to capture a trend. In fact, most private company appraisals aim to represent the value that a company is 'expected to be sold for' i.e. not current market conditions.

Moreover, using the CAPM requires estimating a single asset beta to derive the equity risk premia of a given investment. In the absence of listed proxied for most unlisted infrastructure assets, this estimate of the asset beta is often little more than an educated guess with little to no basis, and no scheme for revising it over time.

This approach also assumes that a single public equity risk premia is a fair representation of the all the risks to which unlisted infrastructure assets are exposed. Academic research has long shown that this is not the case even for listed stocks, which are instead exposed to a number of risk factors in different ways.

Investors in unlisted assets are familiar with the issue of 'smoothed' returns i.e. reported performance that does not capture variability of market prices but instead relies on historical discount rates or minimal and lagged changes to the discount rate.

This reporting phenomenon results in the equally familiar 'stale' pricing issue: reported NAVs are not in line with market prices but instead reflect either a valuation at cost or one that has slowly drifted from its historical cost but is not, in the words of the IFRS 13 standard, *calibrated* using the latest market data.

This is well illustrated by looking at data from funds investing in unlisted infrastructure equity. For example, Table 2 reports the average asset-level discount rate of 15 funds investing in unlisted infrastructure equity with a quasi-exclusive focus on 'contracted projects' as defined in the TICCS® taxonomy, in advanced economies. This data is sourced from the annual and quarterly reports of such funds. The table also shows the asset-level NAV-based total returns, the NAV return volatility and the implied risk-return ratio of these funds.

2. Appraisals are stale

Table 2: The unbelievably smooth risk and return profile of appraisal NAVs (Contracted projects) - data as of 31 December 2020

	3-year	5-year	10-year
Appraisal Discount Rate	7.5%	7.6%	8.3%
Appraisal NAV Total Returns	7.8%	8.4%	8.0%
Appraisal NAV Total Returns Volatility	2.0%	2.0%	1.8%
Implied Sharpe Ratio	3.21	3.54	3.8

Source: Annual and quarterly reports, NAV of assets for 14 funds of unlisted infrastructure equity representing c.USD22bn of reported NAV in 2020

Table 3: Market-implied, discount rates and the realistic risk-adjusted return profile of unlisted infrastructure equity (Contracted Projects) - data as of 31 December 2020*

	3-year	5-year	10-year
Market-implied Discount Rates	6.6%	6.7%	8.2%
Total Returns	6.5%	8.5%	15.3%
Returns Volatility	7.3%	8.2%	11.5%
Sharpe Ratio	0.75	0.91	1.2

Source: EDHECinfra Contracted Projects Advanced Economies Index, includes c.260 live investments and represents c.USD50bn of market value at the end of 2020, available at indices.edhecinfra.com. *last 5 quarters estimated as of Q1 2021.

This can be compared with the private market-implied discount rates and returns for the same segment in Table 3: the EDHEC*infra* Advanced Economies, Contracted Projects Index includes 257 live constituents and 343 since inception in 2000. Its market capitalisation at the end of 2020 was c.USD35bn (we return to this data in detail in section 3).

Clearly, when these funds were created about a decade ago, their discount rates were reasonably in line with mark-to-market data but over time they have not been adjusted to represent the evolution of the market price of risk. As discussed in the introduction, the demand for such assets has increased considerably and the associated risk premia has decreased (a type of yield compression not unlike that seen in other markets), but this trend is not reflected in the risk premia used to produce appraisals for equivalent assets.

As a result of not updating discount rates to reflect market prices, infrastructure funds may have under-reported their private market returns by omitting significant capital gains until 2016 and over-reporting returns afterwards using smooth discount rates above market implied rates. We confirm the finding that find appraisal discount rates are consistently lower than market-implied rates in Section 4.

Still, the most significant issue arising from smooth discount rates and stale NAVs is the underreporting of risk. We know from empirical research in finance that expected returns are better proxied by risk levels than by historical returns (Merton, 1980). If the risk level implied by the reported volatility of appraisals in these funds was true, infrastructure would represent a huge risk-free arbitrage opportunity with a Sharpe ratio of three.

In fact, if the reported volatility was true and fund managers were willing to sell these assets so cheaply on a risk-adjusted basis, they would be generating large negative alpha.

2. Appraisals are stale

Of course, the conclusion should instead be that the volatility of reported NAVs is not a reflection of the true volatility of these investments, as reported previously and elsewhere (Amenc et al., 2020, see for example). Comparing the volatility of appraisal-based returns with the mark-to-market data shown in Table 3, which reflects the evolution of the fair market value of the infrastructure equity market, confirms that the volatility of appraisal NAVs is off by an order of magnitude.

Ergo, appraisal NAVs are stale, do not capture the fair market value of infrastructure investment and cannot be used to reflect the risk of the asset class either.

Next, we describe how to measure the true variance of unlisted infrastructure market prices and document the volatility of unlisted infrastructure investments.

3. Value and risk in unlisted infrastructure equity

3. Value and risk in unlisted infrastructure equity

In the previous section, we showed that the volatility implied by appraisals is off by an order of magnitude. Investors cannot know how volatile infrastructure really is by looking at appraisals, yet they need this data to properly manage their unlisted infrastructure equity investments.

In this section, we describe a novel approach to measuring the value and the risks of unlisted infrastructure equity investments. We have established that reported appraisals and the discount rates used to compute them are not a fair representation of market prices. They are backward-looking, tend to remain at or drift from their historical starting point and, on a risk-adjusted basis, they imply wildly unrealistic valuations given the reported risk. To put simply and bluntly, they are wrong.

An alternative approach consists of using actual secondary market transactions to recalibrate a model of expected returns on a regular basis. In equilibrium (on average), expected returns equal fair market discount rates. This approach addresses the question of finding enough comparable prices at each point in time, which can be addressed by breaking down the question into a multi-factor model of expected returns.

Combined with the largest database of infrastructure investment data built by EDHEC*infra*, the result is a granular estimation of the market price of unlisted investments over time for individual investments as well as entire segments of the universe. In turn, this also enables the measuring of risk in a realistic and consistent manner.

In what follows, we show that such an approach is robust and leads to precise predictions of the observable market prices of unlisted infrastructure equity investments.

We then address in more detail what the different the drivers of market prices are and how they relate to the volatility of unlisted infrastructure equity returns.

3.1 Measuring risk and fair value

3.1.1 The importance of fair value

The importance of assessing illiquid asset such as infrastructure at their fair market value is often underestimated.

Some investors might ask why they should aim to mark illiquid assets like unlisted infrastructure at their 'fair market value' since there is no liquid market to observe frequent transaction prices, and they intend to hold them to maturity. Indeed, one of the reasons for investing in infrastructure is to generate income rather than capital gains, perhaps with a long-term liability matching objective. Hence the frequent buy-and-hold stance taken by long-term investors in infrastructure like large asset owners.

However, if the reason for holding these investments is to collect revenue over long periods, then the present value of these future flows matters. The longer the investment/holding period, the more important it becomes to know how to discount these cash flows to their present value. Since these future cash flows are also dividends and therefore uncertain, their

3. Value and risk in unlisted infrastructure equity

discounting requires knowing what the adequate risk premia should be. Any financial instrument that is purchased to receive cash flows in the future can only be valued by computing the present value of these future cash flows in a manner that incorporates both time value of money and the risk of not receiving these flows.

Moreover, if these future cash flows are used to match liabilities that are themselves discounted to their present value, not discounting the assets at the appropriate rate is not only inconsistent from an economic and accounting perspective, but also leads to an inadequate understanding of the asset-liability position of the investor.

For instance, say the risk-free rate used to discount liability side of the balance sheet was to decrease, leading to an upward revaluation of the liabilities. Then not discounting the cash flows of future infrastructure income used to match liabilities on the asset side with equivalent market rates leads to the wrong assessment of the asset-liability position. In effect, this obviates the liability matching (or hedging) role of infrastructure assets.

Whether it involves dividends or coupons, equity or debt, infrastructure assets need to be valued at their fair value, whatever the liquidity or strategy. The idea that an asset conserves its historical value because it is difficult to sell does not make sense from a financial point of view. [2]

2 - We can draw a very valid comparison with fairly illiquid assets such as corporate bonds. When valuing such instruments, investors refer to a credit spread and the rate of interest to discount future cash flows. It would not occur to long-term investors not to value their corporate bond portfolio at their fair market value. The same logic applies to unlisted infrastructure.

3.1.2 Asset pricing

In private asset classes such as real estate, it is possible to use comparable transactions to assess the evolution of the market price of specific types of property. In the unlisted infrastructure space, there are no such 'comps': infrastructure companies are very different from one another and it is hard enough to find an airport that looks like the one that has to be priced, let alone one that traded in the past three months. To use use 'comps' as one does in real estate, one would probably need to have more transaction data than there are comparable assets in the world.

However, this does not mean that the valuation of infrastructure companies is not driven by common factors. Simply because each company is quite different from the next, this does not imply that all aspects of its market value are determined by its idiosyncratic features. This is a very fundamental point which is often lost to a more 'naive' understanding of the value of private assets: the belief that they are somehow 100% idiosyncratic and can be benchmarked using an absolute rate of return. This is, of course, wrong. In fact, the impact of the Covid-19 pandemic on infrastructure businesses, which we discuss below, reminded many investors that these companies do not exist in a vacuum and are exposed to a range of risks.

Instead, we approach the valuation of the same illiquid, unique and heterogeneous infrastructure companies from the point of view of modern finance: while we cannot use comparable transactions to estimate their latest valuation ratios, it is possible to reduce

3. Value and risk in unlisted infrastructure equity

the number of dimensions of the problem and to estimate the price of such assets for the average buyer or seller by **pricing a few systematic risk factors** that are found in each transaction, irrespective of their idiosyncratic characteristics.

In other words, while infrastructure companies are different from one another, they still belong to a category of assets that have common valuation factors and these factors are what drives the formation of prices in the market.

The fair market value of any unlisted infrastructure equity investment is a function of three components: a future stream of dividends (cash flows), the term structure of risk free rates at the relevant horizon (e.g. some investment have pay-offs 20 years into the future, others 35 years, etc.) and a risk premia.

Given a stream of expected cash flows (which can come from the asset owner), and a term structure of rates (which can be built using the yield of risk-free bonds at the relevant horizons), estimating the fair value of illiquid infrastructure assets boils down to measuring the equity risk premium of each asset.

We propose a method of estimating the fair risk premium applicable to any infrastructure investment in three steps:

First, using the a series of secondary market transaction prices, given the expected stream of dividends, an expected return can be inferred and, using the risk-free curve, a deal risk premia can be extracted for each transaction.

For example, if we observe a secondary market transaction for the equity of infrastructure company j, as before we have:

$$P_j = \sum_{t=1}^{T} \frac{D_{j,t}}{(1 + r_t + \gamma_j)^t}$$

where T is the investment's expected life, r_t is the risk-free rate at each point in time until date T and γ is the deal's risk premia.

Using a numerical solver, the value of γ_j is obtained and represents the equity risk premia required by investors in transaction j, given expected cash flows D_j, the term structure of rates r_t with $t = 1 \ldots T$, in the relevant country at the time of the transaction and the price paid P_j.

Second, each observation of a new γ_j is used to calibrate a risk factor model of the risk premia. We can write:

$$\gamma_j = \beta_1 \times \lambda_1 + \beta_2 \times \lambda_2 \cdots + \omega = \sum_{k=1}^{K} \beta_{j,k} \times \lambda_k + \omega$$

where β_k represents the exposure of company j to risk factor k at the time of the transaction and λ_k is the price or risk premia associated with factor k at that time and ω is a stochastic process representing the idiosyncratic 'noise' in transaction prices.

The risk factor exposures or β_k of each company are based on observable firm financials (e.g. size, leverage, etc. we return to this below) or other observable characteristics and the price of each risk factor are re-estimated each time a new transaction takes place.

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Before observing each transaction, the set of risk factor prices obtained from the previous transaction is used as the prior value for each λ_k and the value of each risk factor price is then updated using the new information (formally, this is known as Bayesian inference and technically as a Kalman filter).

If the model provides a robust explanation of the variance of observed risk premia in actual secondary market transactions, then it can be said that the K factors provide a good model of the systematic price of risk in these transactions. To obtain a quarterly factor price for each risk factor, the average price implied by each deal of the quarter is used.

Finally, once the price of each risk factor is known at the end of each quarter, all that remains is to multiple the risk factor exposure of any infrastructure company for which we seek a fair equity value by the price of each risk factor, so that the estimated equity risk premia $\hat{\gamma}_i$ of company i is given by:

$$\hat{\gamma}_i = \sum_{k=1}^{K} \beta_{i,k} \times \hat{\lambda}_k$$

where $\hat{\lambda}_k$ is the estimated price of risk factor k at the time of valuation. Each firm-specific market risk premia estimated at the end of each quarter is then combined with the term structure of risk-free rates that matches the horizon of the investment and therefore its duration, in the country and on the date of the valuation.

Hence, the quarterly valuations of asset i is obtained by discounting each future dividend at time t at the marked-to-market discount factor $(1 + r_t + \hat{\gamma}_i)^t$.

Several years of research into the determinants of expected returns in unlisted infrastructure companies have led to the selection of several key factors that are found to explain observed transaction prices and their implied expected returns (Bessembinder et al., 2019; Bartram and Grinblatt, 2018; Blanc-Brude and Tran, 2019). We have established that the most relevant, robust and persistent risk factors that explain transaction prices in unlisted infrastructure transactions are:

1. Leverage (senior liabilities over total assets)
2. Size (total assets)
3. Profitability (return on assets before tax)
4. Investment (capex over total assets)
5. Country risk (term spread])
6. A range of control variables including business model and industrial activities according to the TICCS® taxonomy of infrastructure companies, in particular their business model and corporate structure.

Note that these factors are in line with fundamental concepts in asset pricing and corporate finance. For example, higher leverage should increase the cost of equity as per the Modigliani and Miller theorem, and the size, profits and investment are well established risk factors in modern equity valuation since Fama and French. It is also important to note that such an approach rigorously follows the IFRS 13 guidance on measuring fair value in unlisted investments, from focusing on principal markets, to using contemporaneous market inputs and, crucially, calibrating valuations to market inputs at the time of valuation.

3. Value and risk in unlisted infrastructure equity

3.1.3 Input Data

To build a representative view of the investible universe we identify the relevant markets and pick the constituents to create a representative view of the broad-market. We use the following approach:

- Data is collected and structured using TICCS®, an objective and consensus taxonomy that is the industry standard;
- A universe is defined that corresponds to the 25 most active (or principal) markets globally i.e. markets where price signals can be observed reasonably reliably;
- The complete investible universe is identified in each country through market research: a database of several thousands private infrastructure companies and project vehicles is uniquely identified and categorised. Figures 10a, 10b and 10c in the appendix show the breakdown by size of the universe along the business risk, industrial activity and corporate governance pillars of the TICCS taxonomy;
- A large sample of this universe of c.650 firms is built that matches its characteristics over time in terms of each TICCS segment (business risk, industrial activity, corporate governance).
- Each of the firms included in the sample must also meet a number of firm-level inclusion criteria including the availability of its detailed financials. (See the EDHEC*infra* Universe Standard at docs.edhecinfra.com/display/UN)

Thanks to this approach, we avoid two major pitfalls of contributed indices such as the ones based on contributed appraisals:

- We avoid selection bias since the constituents of the broad-market index are sampled from a well-defined and highly relevant population of investments and based on the structure of the market at each point in time.
- We also avoid any survivorship bias since there is no backfilling of the broad-market constituents, instead we 'fill forward' as new infrastructure companies become investible or have to leave the index. This is well illustrated by the number of adverse events in the history of the sampled universe, as discussed in chapter 1.

This sample of the broad market is, for example, used to create the list of constituents of the infra300 index. As is also shown on Figures 10a, 10b and 10c, the infra300 is a close match to the structure of the investible universe. It is not a perfect match due to limitations in the availability of the data. Each firm included in the infra300 index is studied in detail by a team of financial analysts who collect, aggregate and validate its financials, understand its history and prospects, and produce quarterly updated revenue forecasts on the basis of sector and company specific information.

Each year, the investible universe is updated and the sampling recalibrated. Each quarter, the broad-market index constituents are updated for new financial data, new business information and new revenue forecasts.

Next, the data used to calibrate the EDHEC*infra* model of expected returns draws from a dataset of 1,000+ individually

3. Value and risk in unlisted infrastructure equity

validated secondary market transactions of unlisted infrastructure observed over 20 years, 250+ of which are also tracked in EDHEC*infra* indices. Figure 2 shows the coverage of the model input data compared with the infra300 index weights.

3.1.4 Robustness

This approach is robust and predicts market prices well. For the 250+ transactions that correspond to companies tracked in the EDHEC*infra* universe and for which observed secondary market prices are available (the test dataset) we can directly compare observed and model-predicted valuations.

Figures 3a, 3b, 3c and 3d show a comparison between model-predicted IRRs, EV/EBIDTA, price-to-book and price-to-sales ratios with actual values for the test dataset of 250+ observed transactions between 2000 and 2020. Model-predicted prices are accurate and the prediction error is typically within 5% of observed prices as shown in Tables 5 and 4.

Having established that we can measure the evolution of fair market value with a sufficient degree of precision and for a large representative sample, we now review the resulting investment profile of the unlisted infrastructure equity asset class.

3.2 Risk and returns of unlisted infrastructure equity

The approach described above allows us to compute a market-implied discount rate for several hundred investments over the past 20 years years. Figure 4 shows the average discount rate and market risk premia for the 300 constituents of the infra300 index.

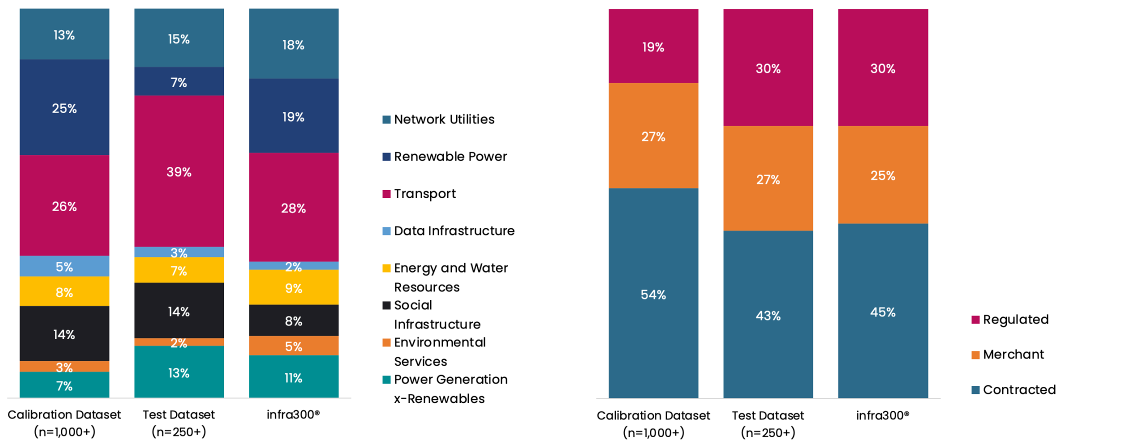
We see that in periods of stress like the 2008 financial crisis, the 2012 European debt crisis and the Covid-19 pandemic, the average risk premia of unlisted infrastructure equity investments tends to increase. We also see that it keep varying as 1/ the price of risk changes over time (the λ_k's discussed above), 2/ the exposure to different risk factor (the β_k's) also change as individual infrastructure companies follow their recycle and the business cycle. Hence, the infrastructure risk premium does not only increase in times of crises but may also be higher because, in aggregate, infrastructure companies take on more leverage, or see their profits decline. Changes in country risk also impact these investments' exposure to the term spread factor. (This is the main reason for the 2012 spike for all assets in southern Europe, which make up about one fifth of the infra300 index by weight.)

The general trend is, unsurprisingly, one of declining yield. Over the past 20 years, the market-implied discount rates of unlisted infrastructure investments has declined from the 12-14% range to a more modest 6-8% range.

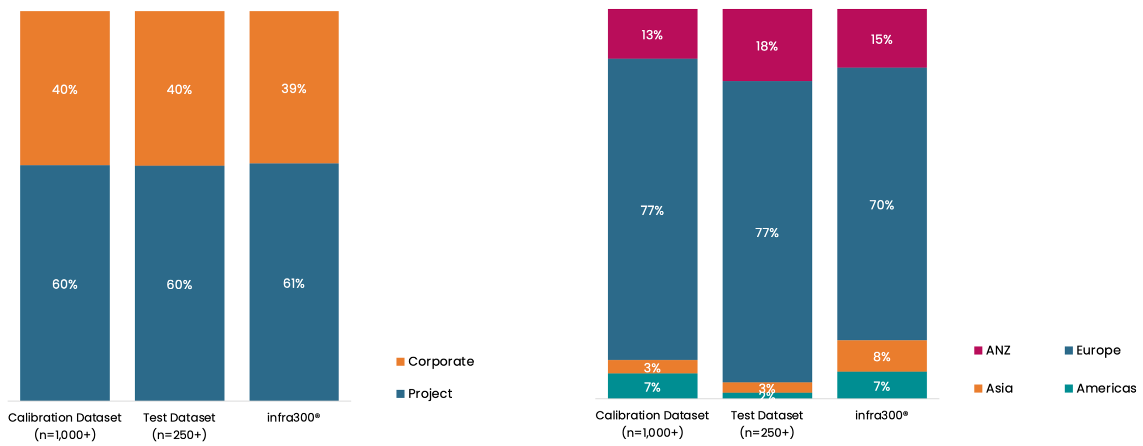
This phenomenon is driven by a number of factors, including a higher demand for such assets and declining interest rates. Indeed, the risk premia has also declined steadily during that period but less than discount rates, as also shown on Figure 4.

3. Value and risk in unlisted infrastructure equity

Figure 2: Distribution of the model input price data by segment: model calibration dataset and model test dataset vs. the infra300® index weights (global market, as of YE2020)



(a) by TICCS® Industrial Activity and Business Risk Segment



(b) by TICCS® Corporate Structure and Geography

Table 4: Estimated vs. Reported Valuation Ratios and model goodness of fit

Ratio	Reported Mean	Estimated Mean	Reported Median	Estimated Median	R2	RMSE*
EV/EBITDA	15.54	15.34	12.98	12.61	0.97	2.27
P/Book	2.37	2.28	1.65	1.59	0.87	0.90
P/Sales	3.35	3.21	2.52	2.32	0.85	1.43

Source: EDHECinfra. *RMSE: root mean squared error

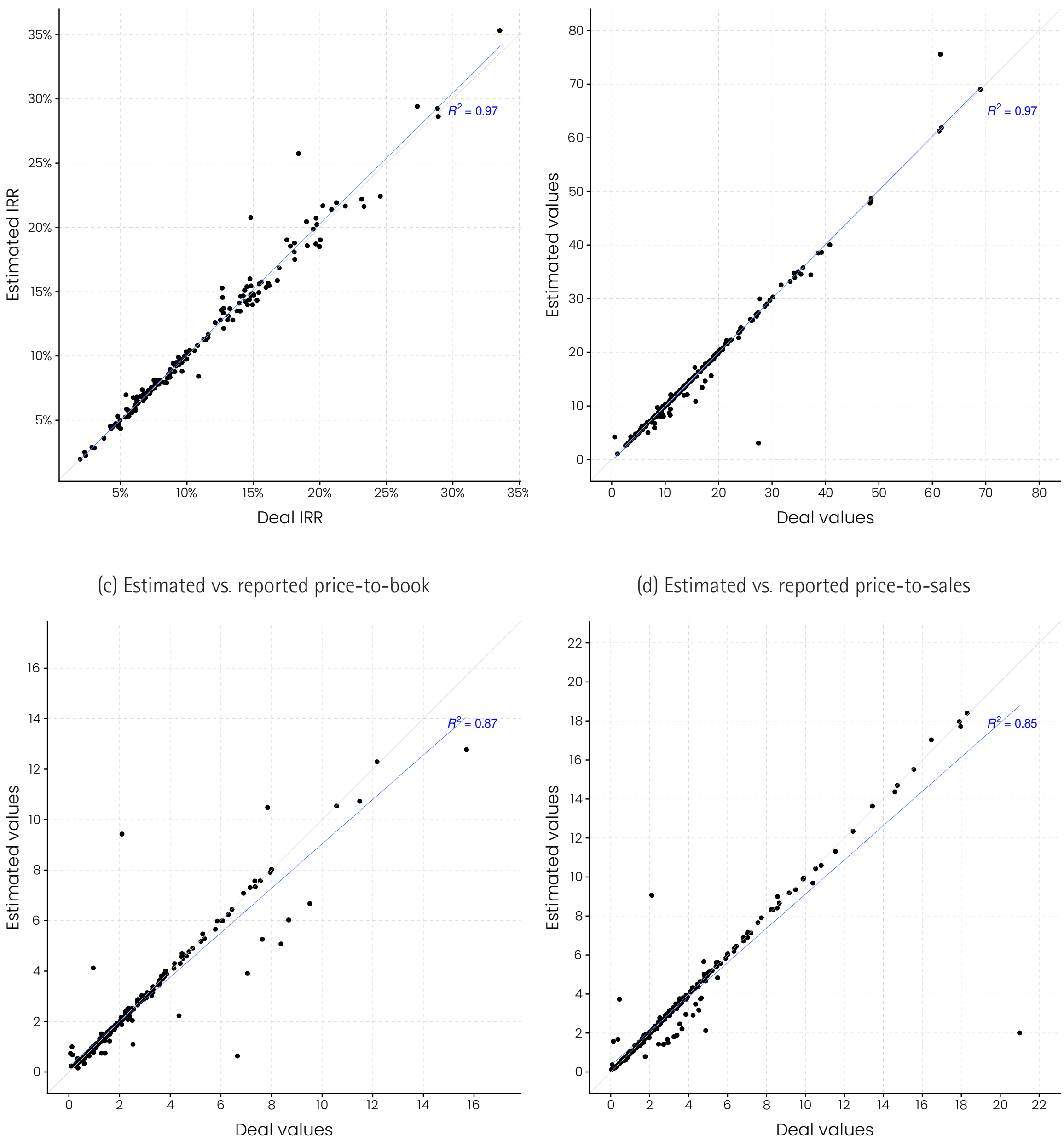
Table 5: Quantiles of Model Errors

0% Quantile	25% Quantile	Median	Mean	75% Quantile	90% Quantile
-5.00%	-1.95%	-0.22%	-0.55%	1.64%	3.85%

Source: EDHECinfra.

3. Value and risk in unlisted infrastructure equity

Figure 3: Predicted vs. reported asset pricing values in the EDHEC*infra* model of unlisted infrastructure equity



(a) Estimated vs. reported deal IRRs

(b) Estimated vs. reported EV/EBITDA

(c) Estimated vs. reported price-to-book

(d) Estimated vs. reported price-to-sales

Source: Annual and Quarterly Reports, EDHEC*infra*

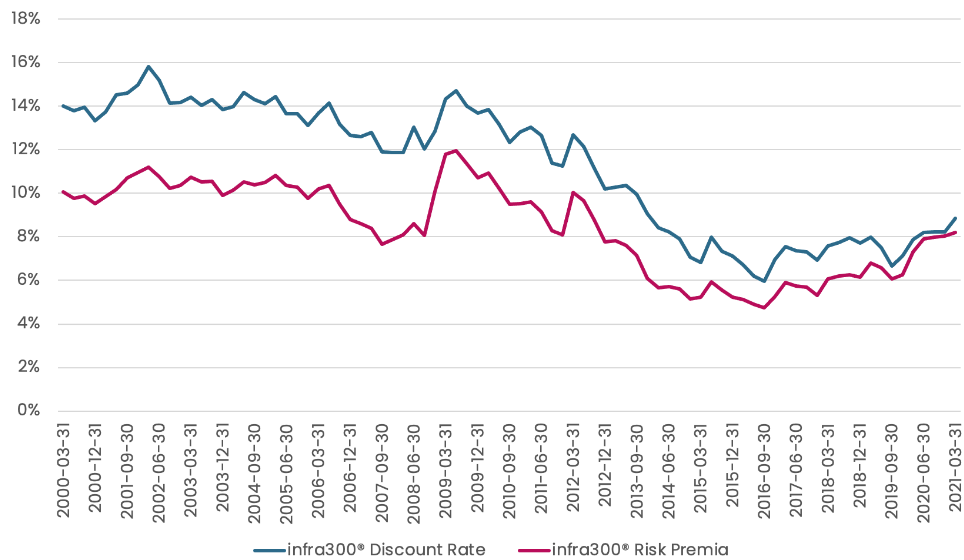
3. Value and risk in unlisted infrastructure equity

Table 6: Total Returns, Risk and Expected Returns of the Unlisted Infrastructure Asset Class and Selected TICCS® Segments, Data as of Q1 2021

Indices	1-year total return	5-year total return	5-year volatility	10-year total return	10-year volatility	99.5% 1-year VaR	Max drawdown	Duration	Expected returns
infra300®	-3.92%	4.08%	9.79%	13.46%	12.69%	21.21%	13.75%	8.69%	8.8%
Global Infrastructure	-1.15%	6.42%	9.68%	14.64%	12.35%	18.97%	13.70%	8.03%	8.6%
Contracted	2.81%	6.62%	8.13%	14.79%	11.26%	14.98%	10.35%	7.67%	7.7%
Merchant	-3.37%	5.82%	11.77%	14.38%	14.63%	27.18%	21.60%	7.70%	10.6%
Global Transport	-4.22%	6.16%	11.45%	15.17%	14.93%	26.90%	22.41%	8.56%	8.7%
Airports	-19.79%	-0.92%	16.22%	11.85%	17.78%	36.00%	34.89%	11.63%	8.9%
Global Projects	0.97%	7.88%	9.07%	15.73%	12.03%	17.02%	13.93%	7.66%	8.2%
Global Wind	-0.25%	7.86%	8.19%	15.22%	10.48%	11.37%	9.55%	7.40%	6.6%
Global Core	0.96%	9.43%	7.33%	15.04%	10.36%	12.46%	11.16%	7.73%	6.2%
Global Core+	-1.88%	10.95%	9.67%	17.94%	12.40%	14.62%	11.86%	9.19%	9.1%
Mid-Market	-0.11%	11.13%	9.40%	16.88%	10.94%	12.07%	10.88%	7.70%	8.8%
Range in bps*	2,260	1,210	890	610	740	2,460	2,530	420	440

Source: EDHECinfra. * maximum - minimum value. As of Q1 2021, local currency returns. 99.5% one-year Cornish Fisher VaR. Expected returns as of Q1 2021. TICCS® segments except for Core and Core+, represented by the first two and the third quantiles of expected returns, respectively and mid-market, which is defined as the second and third size quantiles in the universe.

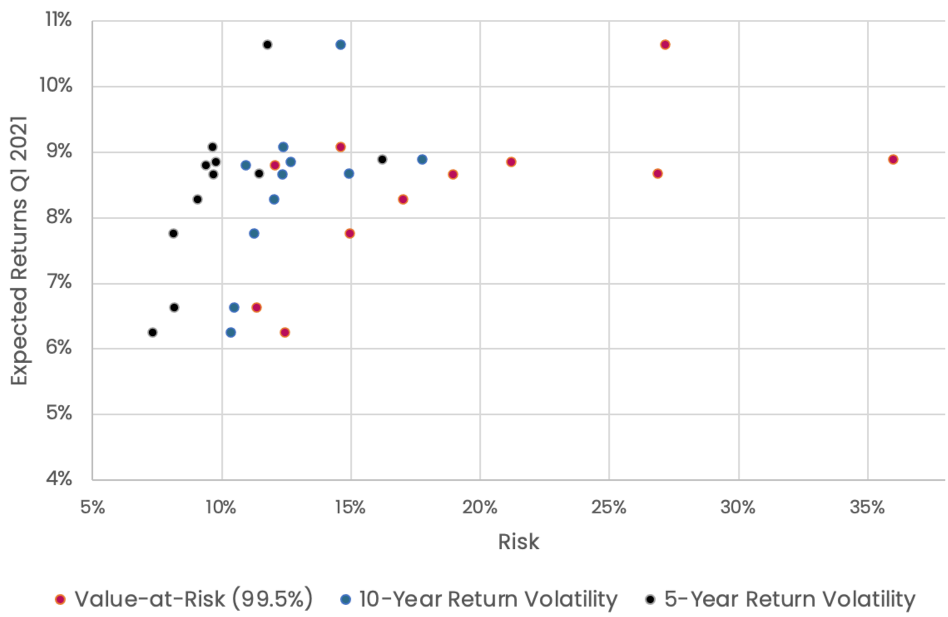
Figure 4: Market Discount Rate of infra300® index



Source: EDHEC*infra*

3. Value and risk in unlisted infrastructure equity

Figure 5: Expected returns vs. 5-year and 10-year volatility and 99.5% value-at-risk in selected segments (see Table 6)



Source: Annual and Quarterly Reports, EDHEC*infra*

We also note that this re-pricing of unlisted infrastructure equity drew to a halt at the end of 2016. Since then yields have stabilised and the average risk premia increased in the wake of continuously decreasing lower interest rates until the end of 2020. In Q1 2021, a significant increase across the term structure of rates led to a higher discount rate, and negative returns across most infrastructure segments.

By definition, this secular change in the average value of unlisted infrastructure (the compression of yields) also adds variance to infrastructure returns, even though it tends to be the result of significant capital gains as unlisted infrastructure turned into a fully-fledged asset asset class during that period. Once this 'great repricing' had taken place after 2016, the valuation of unlisted infrastructure companies, while still exposed to changes in the market price of risk, becomes less variable i.e. returns become less volatile.

Table 6 shows the risk and return metrics for a selection of segments of the infrastructure universe, including the infra300®, the broad-market and TICCS® segments such as global contracted infrastructure or global airports. The table also shows the range (max minus min) for each metric across the different segments, which helps to highlight the differences between them but also the ability of our approach to capture these differences. Results are updated as of Q1 2021.

First, we see that the risk measures including the volatility of returns, value-at-risk or maximum drawdown are in line with the nature of the different segments: contracted

3. Value and risk in unlisted infrastructure equity

infrastructure is less volatile than merchant infrastructure, Core less volatile than Core+ etc. Similarly, despite higher interest rates in Q1 2021, purely contracted infrastructure exhibits positive total returns whereas most other segments do not. In effect, the only two segments in Table 6 with positive returns in Q1 2021 are the ones with the lowest duration.

The range of extreme risk measures is also significant, with a difference of c.2,500 basis points between the lowest and the higher value-at-risk (99.5%) and maximum drawdown measures across these segments.

Consistent with the finding that the upward change in valuations that started after 2009 ended in 2016, the five-year volatility of total returns is significantly lower than its 10-year equivalent in a number of sectors, especially contracted and Core infrastructure (which overlap significantly). On average, total return volatility is 20% lower in the five-year window as of Q1 2021.

Likewise, returns are also much lower since part of the variance of prices that occurred between 2011 and 2021 was driven by capital gains which have abated after 2017. On average, realised total returns are 50% lower in the five-year window.

We also note that the range of realised returns has increased, with a spread between the best and lowest five-year returns in excess of 1,200 basis points, which is twice as large as the spread between the best and the worst 10-year returns (610 basis points).

Despite this significant shift in both expected and realised returns, we note that the relationship between exected returns and and risk continues to hold, with higher expected returns in segments that exhibit historically higher volatility and value-at-risk, as illustrated in Figure 5.

Next, we turn to the determinants of return volatility in unlisted infrastructure.

3.3 DCF decomposition

We now consider the role of each individual component of the market value of infrastructure assets in explaining the change in net-asset-value i.e. how much market prices have changed because of either a change in expected dividends, a change in risk premia or a change in the term structure of interest rates.

Table 7 shows the cumulative impact on the NAV of the actual (realised) change of dividend forecast, interest rates (across the term structure) and risk premia, over a one-, three- and five-year window as of Q1 2021, that is during the more recent period when valuations appear to have stabilised following a period of significant re-pricing.

These impacts are computed to isolate the effect of each factor.

Thus, we see that the aggregate NAV of the global infrastructure segment tracked by EDHEC*infra* (c.600 live firms in 2021) has increased in aggregate by 2.1% since Q1 2016 due solely to changes in expected dividends.

3. Value and risk in unlisted infrastructure equity

Table 7: Average impact on market NAV of change in rates, future dividends and market risk premia on different segments of the unlisted infrastructure equity universe, data as of Q1 2021

Average change in NAV...	..due to change in dividend forecast	..due to change in the term structure of rates	..due to change in equity risk premia
Global Infrastructure			
1-yr chg	-4.0%	-1.2%	-3.9%
3-yr chg	-2.0%	7.4%	-8.2%
5-yr chg	2.1%	9.9%	-9.4%
Contracted			
1-yr chg	-0.2%	-1.0%	-2.7%
3-yr chg	-0.3%	7.3%	-5.6%
5-yr chg	3.6%	9.9%	-7.0%
Merchant			
1-yr chg	-7.20%	-1.30%	-6.90%
3-yr chg	-5.20%	7.20%	-12.50%
5-yr chg	-2.20%	8.50%	-13.20%
Global Transport			
1-yr chg	-6.10%	-0.50%	-5.60%
3-yr chg	-6.70%	8.80%	-11.70%
5-yr chg	-0.40%	11%	-11.70%
Airport			
1-yr chg	-4.40%	-5.20%	-13.70%
3-yr chg	-8.30%	10.20%	-26.40%
5-yr chg	12.40%	13.80%	-27.20%
Global Projects			
1-yr chg	-2.90%	-0.50%	-3%
3-yr chg	-1.70%	7.40%	-7%
5-yr chg	2.80%	9.70%	-8%
Global Core			
1-yr chg	-2.60%	0%	-2.20%
3-yr chg	-0.50%	7.20%	-5.10%
5-yr chg	2.70%	9.40%	-6%
Global Core+			
1-yr chg	-4.70%	-1.60%	-4.40%
3-yr chg	0.10%	8.10%	-9.10%
5-yr chg	8.80%	9.40%	-9.60%

Source: EDHECinfra

However, in the more recent period, lower expected dividends due to the consequences of the Covid-19 lock-downs have had a negative impact on the aggregate NAV.

As expected, this effect is less strong (almost zero) for contracted infrastructure and much larger for merchant assets. Also because of Covid-19, the impact on airports of lower dividends is significant (mostly booked in Q1 2021, hence in the three-year window) but because airports have very long lives it remains limited as the sum total of all future dividends is large relative to the lost dividends of 2020-2022/23.

The cumulative impact of changes in rates is shown in the third column of Table 7. This is the aggregate effect of all rate changes in the segments across two dozen countries and can include simultaneous upward and downward movements of the yield curve in the same quarter in different countries. We see that over a five-year window, the effect has been consistent and large however,

3. Value and risk in unlisted infrastructure equity

explaining between 9 and 10% of the increase in the NAV of assets.

However, this impact is at least partially offset by an increase in the risk premia. In merchant infrastructure and airports, the impact of higher risk premia driven by lower profits in particular is larger than the positive impact of lower rates and therefore, on aggregate, NAV has decreased.

In the global segment however, and particularly in the contracted one, higher risk premia less than offsets lower interest rates and reasonably stable expected dividends, leading to low but positive or close to zero changes in the NAV of assets.

Thus, we see that the impact of changes in rates and risk premia on the variance of the fair value of unlisted infrastructure equity (and therefore on the volatility of returns) is at least as large as that of changes in expected dividends. By focusing only on changes in the cash flows and not on the market price of risk, investors risk seriously mispricing their assets and fail to recognise large changes in market value both positive and negative.

3.4 Risk factors

Finally, we look at the drivers of the risk premia, the estimation of which was described in the asset pricing section above.

As discussed earlier, the equity risk premium of individual companies is the result of the combination of risk factor loadings (or exposures) denoted as β_k's and risk factor prices knowns as λ_k's for factor $k = 1 \ldots K$.

Table 8 shows the average factor exposure in the EDHEC*infra* broad market universe as of Q1 2021. We see that average leverage is high but stable at 77-78%, the average size has increased by about 25% since 2011, while the average term spread has decreased consistently as the term structure flattened. Profits have increased from about 10% return on assets to almost 12% and the investment factor in the tracked universe tends to decrease as more and more firms reach the brownfield stage of their life-cycle.

Next, Figure 6 shows the marginal impact of each factor on the average risk premia, given the factor loading and the factor premium over time.

These results are presented by 'buckets' of low, medium and high exposure to each factor. These buckets are defined in table 12 and descriptive statistics are provided in table 13 both in the appendix

We see that the individual effect of each factor on the risk premia of different infrastructure companies can be quite different:

- Size (Figure 6a): as expected, size has a positive impact on the premia. It can be interpreted as a form of 'relative liquidity' premia: infrastructure companies with a high exposure to the size factor have a consistently higher risk premia. This factor contributes to the variability of the risk premia over time across all levels of

3. Value and risk in unlisted infrastructure equity

Table 8: Average risk factor loadings of the unlisted infrastructure equity universe, Data as of Q1 2021

Date	Leverage	Size	Term Spread	Profits	Investment
Q1 2020	76.97%	1387.91 USD (mn)	1.15%	11.87%	3.59%
Q1 2018	78.12%	1314.85 USD (mn)	1.80%	11.23%	4.35%
Q1 2016	78.30%	1264.73 USD (mn)	1.70%	11.39%	4.95%
Q1 2011	78.49%	1110.95 USD (mn)	3.48%	10.34%	8.85%

Source: EDHECinfra, available at indices.edhecinfra.com

exposure: small or large investments all see the contribution of the size factor increase during bad times and trend down until 2017.

- Leverage (Figure 6b): consistent with theory, leverage is one of the key drivers of the equity risk premia and has the highest marginal contribution. An important difference with Size is the relative difference between leverage buckets: higher leverage commands a significantly higher premia when moving from the low to the medium exposure buckets but much less so between the medium and high buckets.

  This is evidence of a well-known finding in infrastructure project finance research by which high leverage is considered a sign of low asset risk. This is consistent with the most highly leveraged investments such as renewable energy or social infrastructure projects exhibiting the highest leverage (c.90%) because they have a solid contracted business model.

  The leverage factor is also the main contributor to the decrease of the risk premia in absolute terms over time with a reduction in excess of 50%.

- Profit (Figure 6c): also consistent with the financial economics of infrastructure companies, the profit factor premia (λ_k) has a negative sign i.e. higher profits (β_k) leads to a lower aggregate risk premia and negative profits (greenfield or distressed assets) to a higher premia.

  However, this effect is more variable over time depending on the exposure level. Unlike the Size or Leverage factors, the Profit factor does not show signs of a secular reduction in the premia. Instead, it appears to have reverted to its pre-2008 level after peaking in 2012.

  Profitable companies become increasingly less 'discounted' i.e. requiring higher returns in the wake of the 2008 and 2012 crises. In other words, their risk premia became relative higher, irrespective of how profitable infrastructure companies were until 2012, before this effect goes into reverse and investors once again 'value more' (require a lower premium) the more profitable companies.

  This effect is minimal for low profitability companies, significant for companies in the median profitability band and very significant for high profitability investments. Given that positive profits are always valuable, the evolution of this factor over time can be interpreted as a sign of relative risk aversion amongst investors.

  In terms of its marginal contribution to the risk premia however, the Profit factor has

3. Value and risk in unlisted infrastructure equity

the smallest contribution.

- Investment (Figure 6d): Most of the capital expenditure of infrastructure companies takes place during an initial period of development. As expected, a higher loading on the Investment factor i.e., a higher capex/total assets ratio, leads to a higher risk premia. This factor mainly captures the difference between so-called 'greenfield' and 'brownfield' investments (even though this is also captured by the Profit factor).
  The contribution of the Investment factor is higher than that of the Size factor but lower than that of Leverage. This effect tends to decrease significantly over time only for high exposures to the Investment factor. This can be interpreted as a decrease in the premia required to invest in greenfield assets.
- Growth or merchant risk (Figure 6e): When infrastructure companies collect risky revenues either based on demand or traffic, they command a higher risk premia than in they do not (and are either contracted or regulated). Thus this factor (which is binary, companies are either merchant or not) has a positive marginal impact on the premia. We see that while its impact has trended down and exhibits jumps around times of economic crisis (2008, 2020).

Clearly, the dynamic contribution of each factor to the market risk premium of unlisted infrastructure equity over time is an important contributor to the variability of fair market values and to the volatility of returns.

As the infrastructure asset class has developed, its pricing has evolved significantly. From a relatively opaque investment to a sought after alternative asset, unlisted infrastructure went through a process of 'price discovery': while being an illiquid and segmented market, risks are priced rationally and their the evolution is consistent with broader market phenomena including yield compression, relatively easier access to leverage or risk aversion during periods of crisis.

3.5 Conclusion

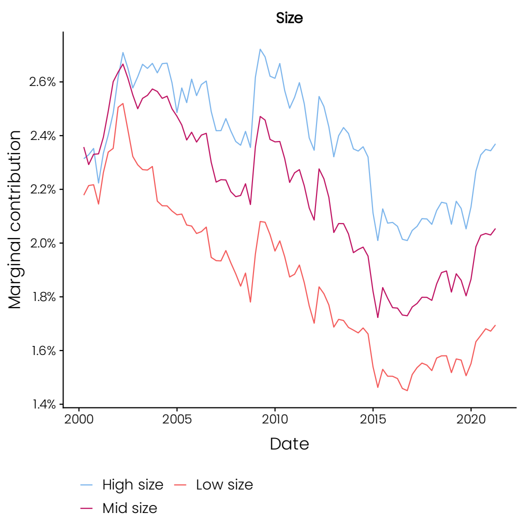
In conclusion, we have shown that it is possible to measure the fair value of unlisted infrastructure equity robustly and accurately and that the resulting time series of returns exhibits a non trivial level of volatility, consistent with the characteristics of the different infrastructure segments as defined by the TICCS taxonomy, as well as the individual exposure of infrastructure assets to certain key risk factors.

An important result is that the volatility of unlisted infrastructure investments is driven by changes in expected dividends only to a point. With a long investment horizon the role of duration or sensitivity to changes in the discount rate is much more significant in explaining the variance of market prices. This discount rate is the combination of the evolution of interest rates and of a risk premia which compensates investors for the uncertainty of future cash flows. Thus, investments in unlisted infrastructure equity can be characterised as investing in a combi-

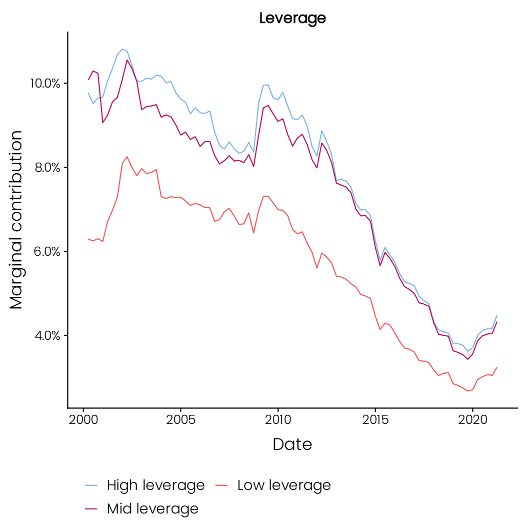
3. Value and risk in unlisted infrastructure equity

Figure 6: Marginal impact of key risk factors on the risk premia of unlisted infrastructure by high/medium/low factor exposure bucket

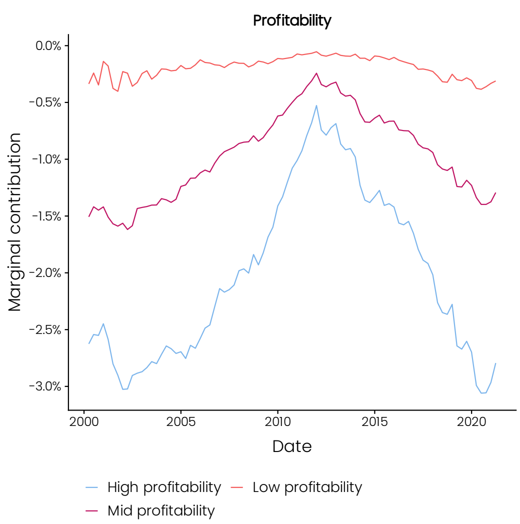
(a) Size



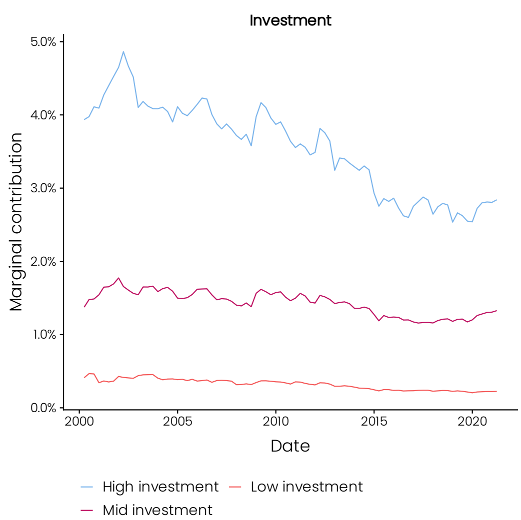
(b) Leverage



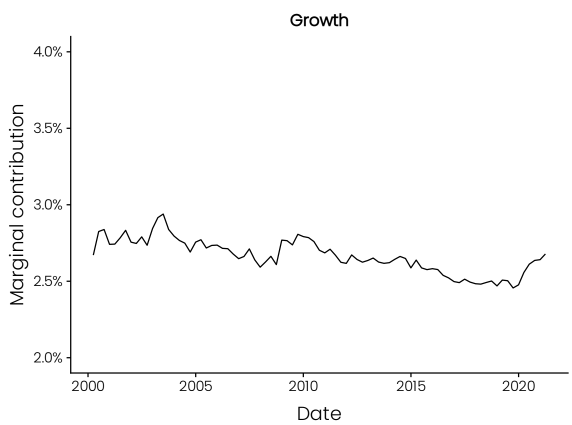
(c) Profit



(d) Investment



(e) Growth or Merchant Risk



Source: EDHEC*infra*

3. Value and risk in unlisted infrastructure equity

nation of exposures to a time-varying (infrastructure) equity risk premia, as well as a significant amount of interest rate risk.

Finally, we see that the realised volatility of infrastructure equity includes a significant period of re-pricing between 2009 and 2016, during which infrastructure assets became more expensive and their yield lower. This 'regime shift' in the pricing of unlisted infrastructure was the result of the asset class coming of age and becoming priced in capital markets. As a result the 10-year volatility stands between 10 and 15%, and 10-year returns as also high, reflecting the significant capital gains of that period. The forward looking volatility of these investments is more likely to resemble that of the 5-year period immediately afterwards, typically ranging between 8 and 12%.

4. Pricing private infrastructure equity risk in public markets

4. Pricing private infrastructure equity risk in public markets

In this section, we conduct a further test of the volatility measures reported in previous section using an alternative source of data: a set of publicly listed infrastructure investment funds.

While it is typically not possible to find proxies of the unlisted infrastructure universe in the public equity market, there is an exception when it comes to a certain subset of this universe: contracted projects in the social infrastructure and renewable energy sectors in the United Kingdom. In what follows, we use data from 14 investment vehicles listed on the London Stock Exchange (LSE) and that have a single activity: investing in the unlisted equity of unlisted infrastructure projects.

Because these firms are listed, they disclose more information than unlisted funds in their annual reports, including their choice of discount rate, the valuation of their portfolios and the sensitivity of asset NAVs to changes in discount rates (i.e. the duration of their assets). We can also observe their market price, returns and volatility using stock market data.

The number of these firms is limited but constituents a natural experiment: together they are a listed basket of unlisted infrastructure equity, with no additional leverage and invested solely in one type of infrastructure, well-defined in the TICCS taxonomy, and in a limited geography (almost exclusively the UK).

We compare the market-implied discount rates of infrastructure funds with their appraisal discount rates and then with the discount rates used in private markets for equivalent assets. We confirm that appraisal discount rates are consistently off by an order of magnitude even though they have trended down alongside market-implied yields, and find that discount rates in private markets have historically been much higher than what public market data implies but have converged since 2016 and become very close since 2018.

Next, we describe the data used for this comparison in more details.

4.1 Data

4.1.1 Infrastructure Fund Data

We use data for 14 infrastructure investment funds listed on the London Stock Exchange, as shown in Table 9. As mentioned above, these vehicles correspond to a listed basket of unlisted infrastructure project equity investments. In other words, for that specific segment of the infrastructure investment universe, they provide a useful reality check of the market value, risk and returns of equivalent and unlisted infrastructure equity investments.

At the end of 2020, they represented an aggregate market value of GBP18.5bn, reported appraisal value of GBP16.5bn and various ownership stakes in more than 800 individual unlisted infrastructure projects. These unlisted equity investments are primarily UK-based, social and renewable energy infrastructure projects as shown on Figure 7.

4. Pricing private infrastructure equity risk in public markets

Table 9: Public Infrastructure Funds Investing in Unlisted Social and Renewable Energy Infrastructure Project Equity, share of total by number of underlying assets, market value and appraisal value.

CODE	ISIN	fund name	investment theme	nb of assets	by market value	by appraisal value
INPP	GB00B188SR50	International Public Partnership	PPP	11.36%	13.85%	13.32%
UKW	GB00B8SC6K54	Greencoat UK Wind	Renewables	3.14%	12.91%	13.39%
GSF	GB00BG0P0V73	Gore Street Energy Storage Fund	Renewables	0.45%	0.79%	0.78%
HICL	GB00BJLP1Y77	HICL Infrastructure	PPP	17.19%	16.24%	16.33%
AERI	GB00BK6RLF66	Aquila European Renewables Income Fund Plc	Renewables	0.90%	1.48%	1.58%
JLIF	GG00B4ZWPH08	John Laing Infrastructure Fund	PPP	9.57%	5.96%	7.05%
BSIF	GG00BB0RDB98	Bluefield Solar Income Fund	Renewables	7.62%	2.70%	2.64%
TRIG	GG00BBHX2H91	The Renewables Infrastructure Group	Renewables	11.51%	13.00%	13.14%
NESF	GG00BJ0JVY01	Nextenergy Solar Fund	Renewables	13.45%	2.97%	3.27%
JLEN	GG00BJL5FH87	JLEN Environmental Assets Group	Renewables	3.74%	3.11%	2.90%
GCP	JE00B6173J15	GCP Infrastructure Investments Limited	PPP	4.04%	4.60%	5.09%
FSFL	JE00BD3QJR55	Foresight Solar Fund	Renewables	8.37%	3.15%	3.22%
3IN	JE00BF5FX167	3i Infrastructure	PPP	2.99%	13.43%	12.32%
BBGI	LU0686550053	Balfour Beatty Glocal Infra	PPP	5.68%	5.82%	4.98%
	Total as of YE 2020			**784**	**GBP18.5bn**	**GBP16.5bn**

Source: London Stock Exchange, Annual Reports, Datastream, EDHECinfra

Table 10: Quantiles of Leverage in Public Infrastructure Funds 2010-2020

Quantile	0%	25%	50%	75%	100%
Median	0%	0%	0%	1%	2%
Mean	0%	4%	6%	10%	13%

Source: Annual Reports

With a few exceptions, these investments and the funds themselves can be grouped into two themes as shows on figure 7b: investors in public-private partnership projects (PPPs) in social infrastructure (TICCS-IC30) and investors in renewable energy projects, especially wind (TICCS-IC7010) and solar power (TICCS-IC720).

Figure 7 also shows the breakdown of the underlying investments made by these funds in other segments of the universe, using a detailed dataset listing each one of their investments in each year since they were created. In aggregate, the TICCS allocation of this group of funds changes over time but remains highly focused on contracted (TICCS-BR10, Figure 7a) projects (TICCS-CG10, Figure 7c) located in in Europe, primarily in the UK (Figure 7e).

Table 9 also shows that the share of the sample by number of underlying assets, by market capitalisation and by appraisal net

4. Pricing private infrastructure equity risk in public markets

asset value are such that, while some funds are much larger than others, no individual fund or theme dominates this sample.

We also report leverage at the fund level in table 10, which shows the quantiles of the leverage reported by the funds in their annual reports over the entire period. Fund leverage is minimal and typically transitory i.e. these funds tend not to have much debt.

Thus, these funds represent a genuine listed proxy of direct holdings of several hundred unlisted infrastructure project equity investments in the social and renewable energy sectors in the UK.

4.1.2 Private Market Equivalent

To compare this listed basket of unlisted infrastructure project equity to a similar portfolio of unlisted assets, we build a custom portfolio using the data from the EDHEC*infra* universe.

This private market custom index is designed to have exactly the same TICCS and geographic weights as the listed one, following the weights shows in Table 7 at each point in time.

It consists of 141 wholly-owned underlying assets in 2020 and represents GBP16bn of market value at the end of 2020. All assets in this index are priced on quarterly basis using the methodology described in the previous chapter.

Next, we compute market-implied discount rates for these funds and compare them with appraisal discount rates and private market discount rates for the same investments.

4.2 Market-Implied Discount Rate

As argued above, the main issue with the discount rates used in the appraisal of unlisted infrastructure equity investments is their lack of market-testing or calibration to market inputs. We illustrate this point by computing the market-implied discount rates of the public infrastructure funds described above.

Since these publicly quoted vehicles solely hold the equity of unlisted infrastructure assets, we can use their public prices in combination with their reported unlisted asset appraisal discount rates to derive a market-implied equivalent of their discount rates using the market premium to their NAVs. Indeed, the actual (market-implied) discount rate of these funds' unlisted assets can be written as a function of its actual market yield and a factor adjusting for the difference.

For simplicity, assume a Gordon dividend growth model to represent asset values. We have:

$$P_t = \frac{D}{y_t - g} \text{ and,} \tag{4.1}$$

$$NAV_t = \frac{D}{r_t - g} \tag{4.2}$$

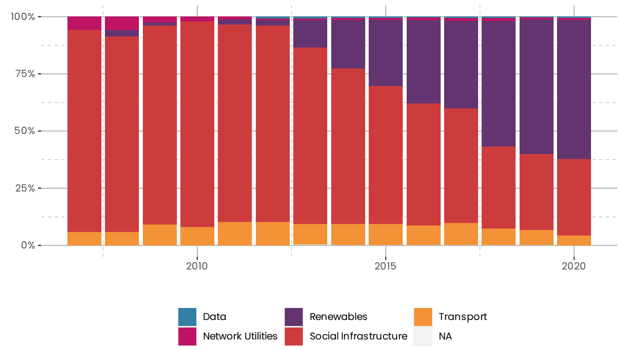
With P_t the market price of an asset, D the dividend payout, y the market expected rate of return or yield and g the perpetual dividend growth rate. NAV_t is the appraisal NAV and r the appraisal discount rate. It follows that the ratio of the market price to the appraisal NAV

4. Pricing private infrastructure equity risk in public markets

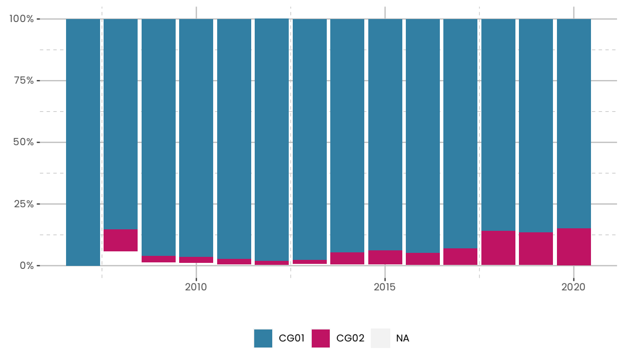
Figure 7: TICCS® Segmentation of the Unlisted Infrastructure Investments of 15 Public Infrastructure Funds

(a) By Business Model

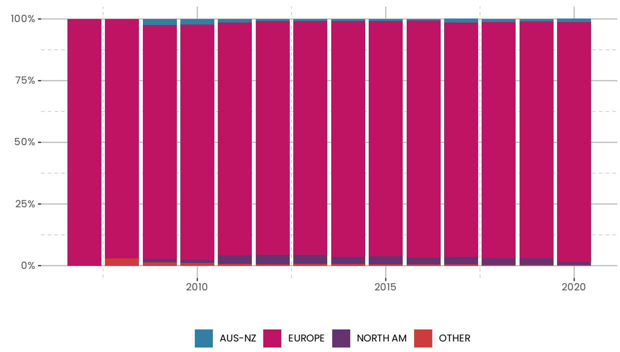
(b) By Industrial Activity



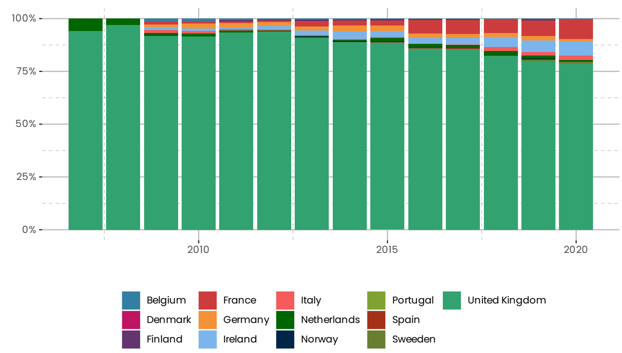
(c) By Corporate Structure



(d) By Region



(e) By European Country

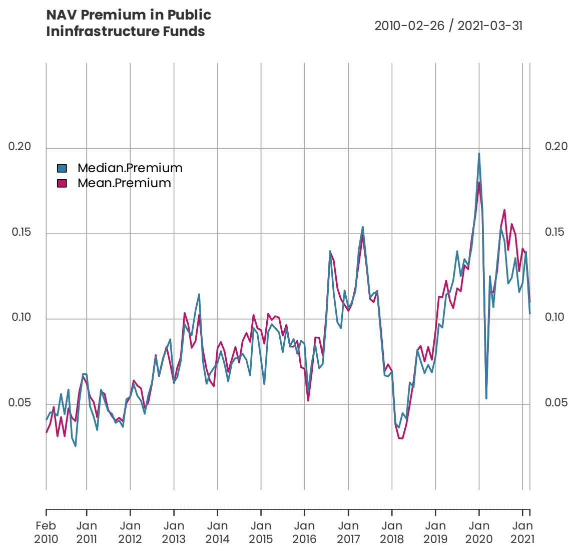


Source: Annual and Quarterly Reports, EDHEC*infra*

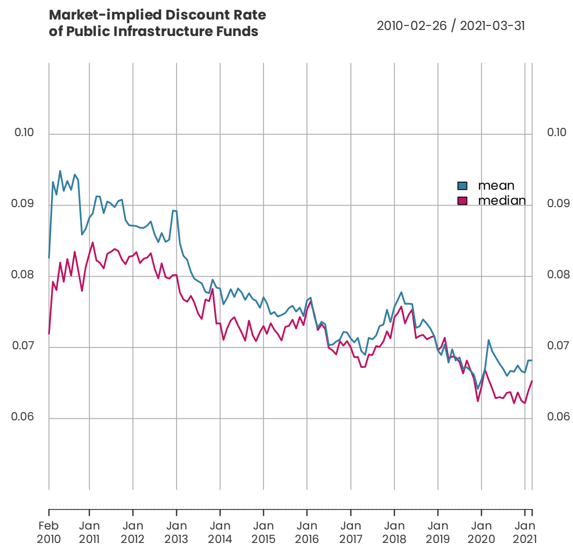
4. Pricing private infrastructure equity risk in public markets

Figure 8: Average Quarterly NAV Premium and Market-Implied Discount Rates of Public Infrastructure Funds Investing in Social and Renewable Energy in the UK, Q1 2010 - Q1 2021

(a) NAV Premium

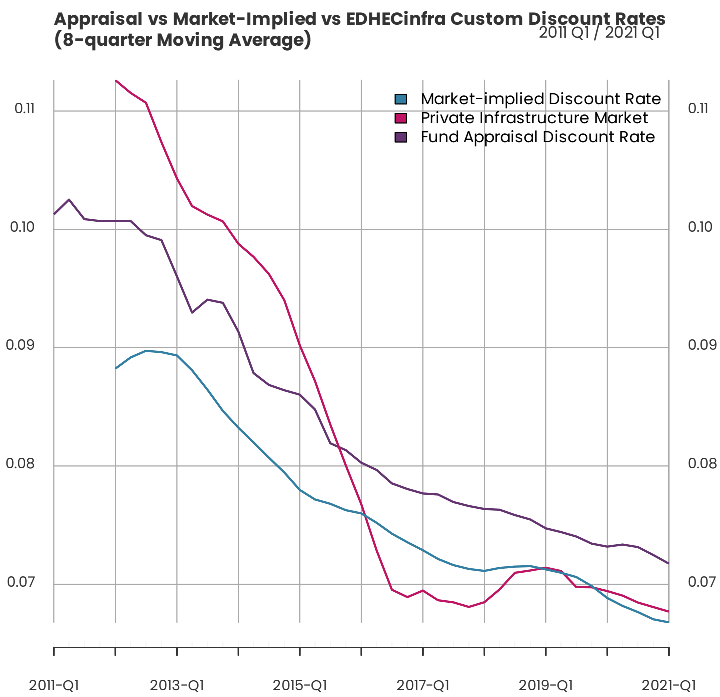


(b) Market Implied Discount Rate



Source: Datastream, Annual and Quarterly Reports, EDHEC*infra*

Figure 9: Rolling average of Appraisal Discount Rates and Market-Implied Discount Rates



Source: Datastream, Annual and Quarterly Reports, EDHEC*infra*

4. Pricing private infrastructure equity risk in public markets

Table 11: Average Reported Discount Rates vs. Market-Implied Discount Rates of PPP and Renewable Energy Infrastructure funds

Period	Market implied discount rate	Appraisals		Private Infrastructure Market	
		Discount rate	Diff. w/ market	Discount rate	Diff. w/ market
2010-2014	8.28%	9.11%	0.83%	9.91%	1.63%
2015-2018	7.26%	7.88%	0.62%	7.00%	-0.25%
2019-2020	6.70%	7.61%	0.91%	6.80%	0.10%

Source: Annual Reports, Datastream, EDHECinfra.

is:

$$\frac{P_t}{NAV_t} = \frac{D}{y_t - g} / \frac{D}{r_t - g} \tag{4.3}$$

$$= r_t / y_t \tag{4.4}$$

And the market-implied yield can be written as a function of the appraisal discount rate, reported NAV and the market price of the asset.

$$y_t = r_t / \frac{P_t}{NAV_t} \tag{4.5}$$

$$= r_t / (1 + \delta_t) \tag{4.6}$$

with δ_t the NAV premium of the asset. That is, when an asset trades above its NAV (at a premium), its market discount rate or yield is equal to its appraisal NAV discount rate adjusted by a factor equal to $1/(1+\delta_t)$ with $\delta > 0$ i.e. a lower effective discount rate than its appraisal discount rate.

Figure 8 shows the average NAV premium (8a) and the average market-implied discount rate (8b) for the 14 funds. We find that these funds have been trading at a premium to their NAV at least since 2010 with a premium ranging between 5 and 15%.

Their average market-implied discount rates have been trending down from 8-9% in 2010 to 6-7% in 2020, following the familiar yield compression trend already discussed in the previous section.

Next, we compare the average market-implied discount rate of these funds with their appraisal discount rate and that of the private market custom index. Table 11 and Figure 9 show that the average difference between market-implied discount rates and appraisals is constant over time: appraisal do decline over time but they never catch up with the level of discount implied by market prices.[3].

Conversely, private market discount rates[4] represented by the EDHEC*infra* custom index, show a clear convergence with their listed equivalent: between 2010 and 2015, private assets were relatively cheap compared with the public price and commanded a significantly higher discount rate. This is, again, a familiar picture of the higher return/discount rates of unlisted infrastructure before 2016, as discussed earlier.

As the private market yield is driven down by the high demand for these assets, it overshoots the public market-implied yield between 2016 and 2018, by which time, unlisted infrastructure PPPs and renewable investments are effectively more expensive (have a lower yield) than their publicly listed equivalent.

From 2018 onwards however, they have converged and become very close. Table 11

3 - Table 14 in the appendix shows these result by investment theme

4 - Duration-adjusted

4. Pricing private infrastructure equity risk in public markets

shows that the difference between the public market-implied and private-market discount rates decreases steadily over time and is less than 10bp [5] at the end of the period.

5 - in fact not significantly different from zero

There is no such convergence with appraisal discount rates which maintain 80-90 basis points average difference with market-implied rates, confirming that they are not market-tested.

4.3 Conclusion

Thus, two comparable sets of underlying investments exposed to similar risk factors, one listed and one not are found to exhibit similar levels of expected returns and risk pricing after 2018, following a decade long period of convergence.

This finding confirms both that unlisted infrastructure went through a period of repricing prior to 2016 which led to significant capital gains but also more variability of prices i.e. volatility of returns, and that from 2017 onwards, infrastructure valuations have entered into a more stable state, in line with the price of risk found in capital markets.

This results provides a powerful robustness check of the risk factor model described in the previous section and the historical decline and stabilisation of the price of risk it documents empirically.

5. Conclusions

5. Conclusions

In conclusion, in this paper we have shown that the volatility of investments in unlisted infrastructure equity is much higher than suggested by reported appraisals. This issue is frequently found in private investments and referred to as either 'stale' pricing or 'smoothed' returns. The lack of market testing and calibration of appraisal discount rates means that even if they are adjusted over time they tend to 'drift' from their starting point and never catch up with current market prices.

With discount rates thus calibrated, the change in NAV of unlisted assets cannot reflect the true risk of these assets and instead leads to unrealistically low volatility and a clearly unbelievable risk-return profile.

We argue that this is an serious impediment to the development of the infrastructure asset class which is in need of robust measures of market risk in order to be integrated in asset allocations, risk and prudential management and benchmark performance compensations.

We show that it is possible to measure the evolution of the fair value of unlisted infrastructure equity with a sufficient degree of precision and robustness to also measure the risk of the asset class. This risk is the result of the changes in expected dividends, the term structure of risk-free rates and an infrastructure equity risk premia which is specific to each firm but is fomed in the market as a combination of systematic risk factor premia.

Using a multi-factor approach, we show that this risk premia can be decomposed and measured over time using data from the secondary market for unlisted infrastructure, and recycled to price other assets that have not traded at that point in time.

Thus, a view on future cash flows and the evolution of interest rates, both of which are available to asset owners - in combination with a firm-specific risk premia defined by the investment's exposure to key risk factors like size, leverage or profitability - allows the continuous valuation of unlisted and illiquid infrastructure equity investments.

Using this approach, we arrive at several stylised facts that characterise the risk of unlisted infrastructure equity investments:

- The unlisted infrastructure equity risk premia has decreased considerably since 2008. This shift or re-valuation took place in two steps: the price of risk first decreased steadily until 2016. It then stopped decreasing, and more recently has risen by a smaller margin for all infrastructure asset types in the wake of the Covid-10 pandemic.

  The oft-mentioned notion that private infrastructure valuations have risen continuously due to the high demand for these assets must be qualified insofar as the maximum average valuations ("peak infra") in recent years were reached at the end of 2016.

  Since then, unlisted infrastructure risk premia and expected returns have remained at a level seemingly aligned with (rare but) comparable capital market

5. Conclusions

equivalents.

- A significant proportion of the realised volatility of unlisted infrastructure returns in the past 15 years is the result of this re-valuation i.e. one-way capital gains that were created by a significant increase in the demand for such assets.

- Unlisted infrastructure remains volatile and exposed to the same risks, but realised volatility over the past decade is not the best proxy of the asset class forward-looking volatility.

- We shows that in the more recent period (past five years), the volatility of private infrastructure asset prices has been mostly driven by a combination of movements in interest rates and risk premia, the magnitude of which is much greater than changes in future dividends. It follows that the duration of unlisted infrastructure equity (its sensitivity to discount rate changes) is the most informative forward-looking measure of risk. We report significant levels of duration between 7.6% to 11.6% in Q1 2021 depending on the TICCS segment of the sector. Duration presents the advantage of combining the impact of changes in the risk premia (which is firm specific) with that of interest rates, which is market specific.

- The risk premia of individual private infrastructure companies is driven by a combination of micro-economic and macro-economic factors, the risk premia of which has also considerably changed over the past two decades. These changes in the determinants of the price of equity risk are at the heart of the volatility of private infrastructure. In particular:

1. The Leverage factor premium, which is the largest contributor to the discount rate has halved since 2010 but reversed its course in 2020. In line with financial theory, higher leverage commands a higher premia, even though this effect tails off rapidly on average for highly leveraged assets, which, by design, tends to be the safest infrastructure projects.

2. The Size factor premium exhibits more short term volatility and reached a floor in 2015. This factor can be considered a proxy of the relative liquidity of infrastructure investments: *ceteris paribus* larger assets command a higher premia. This result sometimes seems to contradict the anecdotal evidence that large 'trophy' assets command higher prices (and therefore lower premia) in the market. However, this suggestion ignores the independence of factors premia. High prices for highly-demanded large assets are the result the combined effect of all risk factors. Indeed, large sought-after infrastructure companies also tend to be highly profitable.

3. The Profit factor premium is the the only negative contributor to aggregate risk premia: higher profits lead to lower risk premia (higher valuations). This factor premium has achieved a

5. Conclusions

full rotation since 2000, reaching a peach in 2012 when higher profits barely achieved a higher valuation and returning to its 2000 level by 2020. This factor can be interpreted as a sign of risk greater aversion amongst buyers of unlisted infrastructure. In this sense, it reached its lowest level in 20 years just before the Covid-19 pandemic. Negative profits (leading to a higher premium) are also a contributor to the so-called 'greenfield' premium which characterises early development projects.

4. The Investment factor premia exhibits the most stability over the past 20 decades. High investment (capex) in infrastructure companies is related to the life-cycle of the firm, including the greenfield phase during which sinking larger amounts of capex commands a higher premium.

Thus, the forward-looking volatility of private infrastructure equity investments is reflected in expected returns i.e. discount rates. The secular trend towards lower expected returns in this asset class reached a level of 6-8% in recent years for the asset class as a whole, which is aligned with the asset class cash yield.

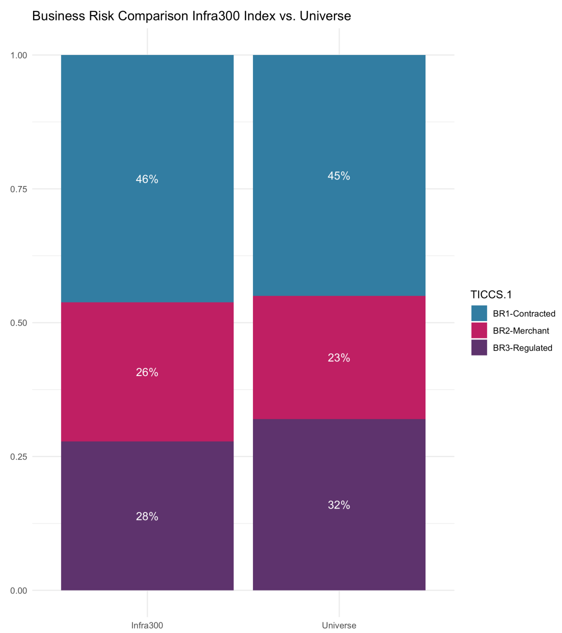
We conclude that a robust measure of unlisted infrastructure equity is possible because it relies on the an equally robust asset valuation technology. The results highlight the importance of understanding duration to anticipate changes in the market values of unlisted infrastructure equity and that, for a given stream of cash flows, a large part of this risk is driven by a country-specific (or macro) component (the yield curve) and a firm-specific (but systematic) component which is the combination of the risk factor exposures and the market price of these same risk.

We provide a further validation of these results by showing that for a well-defined subset of the asset class (renewable energy and social infrastructure projects in the UK), for which a credible publicly listed proxy can be found, expected returns have effectively converged over a decade and are now aligned.

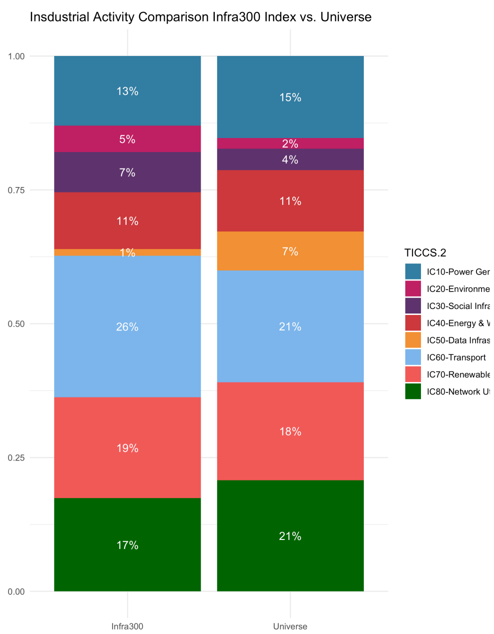
6. Appendix

6. Appendix

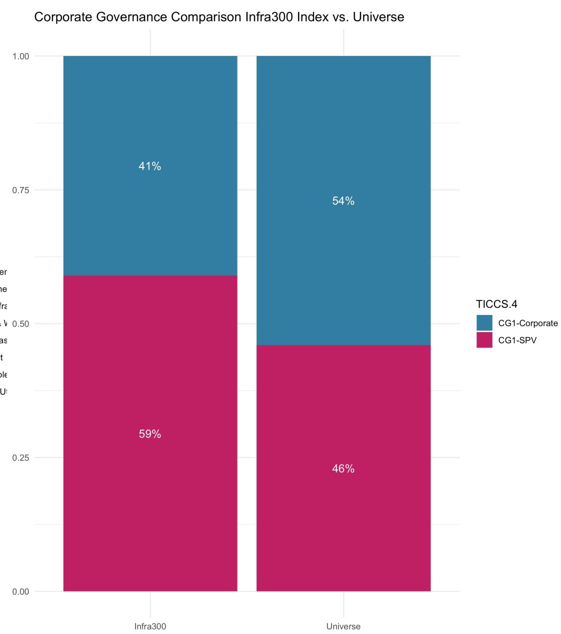
Figure 10: Investible Universe and infra300 Equity Index Weights



(a) by TICCS® Business Risk Segment



(b) by TICCS® Industrial Activity Segment



(c) by TICCS® Corporate Structure Segment

Table 12: Definition of Factor Exposure Buckets

	Low	Medium	High
Leverage	<= 70%	70% - 90%	>90%
Size	<= 200mn	200mn - 1bn	>1bn
Profitability	<= 6%	6% - 12%	>12%
Investment	<= 5%	5% - 10%	>10%
Term spread	<= 0.5%	0.5% - 2%	>2%

6. Appendix

Table 13: Factor Buckets Descriptive Statistics

	Share of universe	Mean value	Median value	Standard deviation
High leverage	40%	97.5%	99.4%	3.2%
Low leverage	33%	48.7%	52.6%	17.1%
Mid leverage	28%	80.9%	82.2%	5.9%
High size (USDm)	26%	4,447	2,394	5,425
Mid size (USDm)	40%	476	443	206
Low size (USDm)	35%	82	62	63
High profitability	29%	22.4%	17.7%	15.0%
Mid profitability	44%	8.6%	8.5%	1.6%
Low profitability	27%	2.2%	2.6%	4.4%
High investment	9%	19.0%	15.8%	8.0%
Mid investment	18%	6.9%	6.9%	1.2%
Low investment	74%	1.1%	0.4%	1.4%
Merchant	24%	NA	NA	NA
Not Merchant	76%	NA	NA	NA

Table 14: Average Reported Discount Rates vs. Market-Implied Discount Rates of PPP and Renewable Energy Infrastructure funds

		Median Discount Rates			Mean Discount Rates		
Theme	Period	Appraisal	Market-Implied	Difference*	Appraisal	Market-Implied	Difference*
PPP Funds	2010-2014	8.58%	7.96%	610	9.17%	8.55%	619
PPP Funds	2015-2018	7.80%	7.04%	765	7.99%	7.36%	634
PPP Funds	2019-2020	7.30%	6.75%	552	7.92%	6.97%	956
Renewables Funds	2010-2014	8.40%	6.98%	1,417	8.60%	7.29%	1,312
Renewables Funds	2015-2018	7.54%	7.34%	196	7.70%	7.38%	319
Renewables Funds	2019-2020	7.03%	6.55%	476	7.35%	6.67%	684

Source: Annual Reports, Datastream, EDHEC*infra*. *basis points

6. Appendix

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About The Long-Term Infrastructure Investors Association

About The Long-Term Infrastructure Investors Association

Founded in 2014 by investors sharing the same long-term DNA, LTIIA is a not-for-profit international association; it gathers both asset owners and fund managers with responsibilities over long-term and open-ended infrastructure investment mandates across the world that collectively manage over US dollars 350bn of assets in Infrastructure.

LTIIA works with a wide range of stakeholders, including infrastructure investors, development banks, policy-makers, regulators and academia on supporting long-term, responsible deployment of private capital to public infrastructure globally , by bringing transparency, sharing best practices and through standardization, benchmarking and research . Our principal activities revolve around:

- Public advocacy: we convey investors' expectations and perspectives to governments, multilateral institutions & regulators as they design policy frameworks on infrastructure
- Infra as an asset class: by supporting industry-led initiatives and research by academic centers such as EDHEC-Infra, we support data collection & development of analytical tools & performance benchmarks for the investment community
- Sharing best practices: We promote the highest level of Environmental, Social and Governance for efficient, inclusive & resilient infrastructure at the service of sustainable development. We believe that the alignment of interests can ensure both a consistent quality of service for the public body and attractive returns over time.
- Convening power: We organize events, seminars and webinars with senior representatives from public & private sectors on infrastructure investment issues

About EDHEC Infrastructure Institute-Singapore

About EDHEC Infrastructure Institute-Singapore

EDHEC*infra* addresses the profound knowledge gap faced by infrastructure investors by collecting and standardising private investment and cash-flow data and running state-of-the-art asset pricing and risk models to create the performance benchmarks that are needed for asset allocation, prudential regulation, and the design of new infrastructure investment solutions.

Origins

In 2012, EDHEC-Risk Institute created a thematic research program on infrastructure investment and established two Research Chairs dedicated to long-term investment in infrastructure equity and debt, respectively, with the active support of the private sector.

Since then, infrastructure investment research at EDHEC has led to more than 20 academic publications and as many trade press articles, a book on infrastructure asset valuation, more than 30 industry and academic presentations, more than 200 mentions in the press, and the creation of an executive course on infrastructure investment and benchmarking.

A testament to the quality of its contributions to this debate, EDHEC*infra*'s research team has been regularly invited to contribute to high-level fora on the subject, including G20 meetings.

Likewise, active contributions were made to the regulatory debate, in particular directly supporting the adaptation of the Solvency-II framework to long-term investments in infrastructure.

This work has contributed to growing the limited stock of investment knowledge in the infrastructure space.

A Profound Knowledge Gap

Institutional investors have set their sights on private investment in infrastructure equity and debt as a potential avenue toward better diversification, improved liability-hedging, and reduced drawdown risk.

Capturing these benefits, however, requires answering some difficult questions:

1. **Risk-adjusted performance measures** are needed to inform strategic asset allocation decisions and monitor performance;
2. **Duration- and inflation-hedging properties** are required to understand the liability-friendliness of infrastructure assets;
3. **Extreme risk measures** are in demand from prudential regulators, among others.

Today none of these metrics is documented in a robust manner, if at all, for investors in privately held infrastructure equity or debt. This has left investors frustrated by an apparent lack of adequate investment solutions in infrastructure. At the same time, policy-makers have begun calling for a widespread effort to channel long-term savings into capital projects that could support long-term growth.

To fill this knowledge gap, EDHEC has launched a new research platform, EDHEC*infra*, to collect, standardise, and produce investment performance data for infrastructure equity and debt investors.

Mission Statement

Our objective is the creation of a global repository of financial knowledge and investment benchmarks about infrastructure equity and debt investment, with a focus on delivering useful applied research in finance for investors in infrastructure.

We aim to deliver the best available estimates of financial performance and risks of reference portfolios of privately held infrastructure investments and to provide

About EDHEC Infrastructure Institute-Singapore

investors with valuable insights about their strategic asset allocation choices in infrastructure, as well as to support the adequate calibration of the relevant prudential frameworks.

We are developing unparalleled access to the financial data of infrastructure projects and firms, especially private data that is either unavailable to market participants or cumbersome and difficult to collect and aggregate.

We also bring advanced asset pricing and risk-measurement technology designed to answer investors' information needs about long-term investment in privately held infrastructure, from asset allocation to prudential regulation and performance attribution and monitoring.

What We Do

The EDHEC*infra* team is focused on three key tasks:

1. **Data collection and analysis**: we collect, clean, and analyse the private infrastructure investment data of the project's data contributors as well as from other sources, and input it into EDHEC*infra*'s unique database of infrastructure equity and debt investments and cash flows. We also develop data collection and reporting standards that can be used to make data collection more efficient and more transparently reported. This database already covers 15 years of data and hundreds of investments and, as such, is already the largest dedicated database of infrastructure investment information available.

2. **Cash- flow and discount-rate models**: Using this extensive and growing database, we implement and continue to develop the technology developed at EDHEC-Risk Institute to model the cash flow and discount-rate dynamics of private infrastructure equity and debt investments and derive a series of risk and performance measures that can actually help answer the questions that matter for investors.

3. **Building reference portfolios of infrastructure investments**: Using the performance results from our asset pricing and risk models, we can report the portfolio-level performance of groups of infrastructure equity or debt investments using categorisations (e.g., greenfield vs. brownfield) that are most relevant for investment decisions.

Partners of EDHEC*infra*

Monetary Authority of Singapore

In October 2015, Deputy Prime Minister of Singapore Tharman Shanmugaratnam announced officially at the World Bank Infrastructure Summit that EDHEC would work in Singapore to create "usable benchmarks for infrastructure investors."

The Monetary Authority of Singapore is supporting the work of the EDHEC Singapore Infrastructure Investment Institute (EDHEC*infra*) with a five-year research development grant.

Sponsored Research Chairs

Since 2012, private-sector sponsors have been supporting research on infrastructure investment at EDHEC with several Research Chairs that are now under the EDHEC Infrastructure Investment Institute:

About EDHEC Infrastructure Institute-Singapore

1. The EDHEC/NATIXIS Research Chair on the Investment and Governance Characteristics of Infrastructure Debt Instruments, 2012-2015
2. The EDHEC/Meridiam/Campbell-Lutyens Research Chair on Infrastructure Equity Investment Management and Benchmarking, 2013-2016
3. The EDHEC/NATIXIS Research Chair on Infrastructure Debt Benchmarking, 2015-2018
4. The EDHEC / Long-Term Infrastructure Investor Association Research Chair on Infrastructure Equity Benchmarking, 2016-2019
5. The EDHEC/Global Infrastructure Hub Survey of Infrastructure Investors' Perceptions and Expectations, 2016

Partner Organisations

As well as our Research Chair Sponsors, numerous organisations have already recognised the value of this project and have joined or are committed to joining the data collection effort. They include:

- The Global Infrastructure Hub;
- The European Investment Bank;
- The World Bank Group;
- The European Bank for Reconstruction and Development;
- The members of the Long-Term Infrastructure Investor Association;
- Over 20 other North American, European, and Australasian investors and infrastructure managers.

EDHEC*infra* is also :

- A member of the Advisory Council of the World Bank's Global Infrastructure Facility
- An honorary member of the Long-term Infrastructure Investor Association

EDHEC Infrastructure Institute Publications

EDHEC Infrastructure Institute Publications

EDHECinfra Methdologies & Standards

- The Infrastructure Company Classification Standard (TICCS) - Updated March 2020
- Credit Risk Methodology - April 2020
- Infrastrcuture Index Methdology Standard - Updated March 2020
- Global Infrastructure Investment Data Standard - Updated March 2020
- Unlisted Infrastructure Valuation Methodology - A Moderm Approach to Measuring Fair Value in Illiquid Infrastructure Investments - Updated March 2020

Selected EDHEC Publications

- Amenc, N. & F. Blanc-Brude. "The Cost of Capital of Motorway Concessions in France - A Modern Approach to Toll Regulation" (September 2020)
- F. Blanc-Brude & A. Gupta. "Unlisted INfrastructure Performance Contribution, Attribution & Benchmarking" (July 2020)
- Whittaker, T. & R. Tan. "Anatomy of a Cash Cow: An In-depth Look at the Financial Characteristics of Infrastructure Companies." (July 2020)
- Amenc, N., F. Blanc-Brude, A. Gupta, L. Lum. "Investors Should Abandon Absolute Returns Benchmarks - Lessons from the Covid-19 Lockdowns" (June 2020)
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Notes

Notes

For more information, please contact:
Tina Chua on +65 6438 0030
or e-mail: tina.chua@edhec.edu

EDHEC Infrastructure Institute
EDHEC Asia-Pacific
One George Street - #15-02
Singapore 049145
Tel.: +65 6438 0030

edhec.infrastructure.institute